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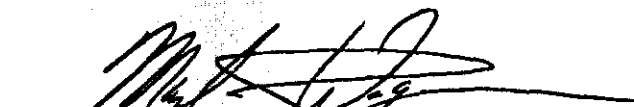
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FINAL REPORT

Administrative Order on Consent
Remedial Investigation/Feasibility Study
Avtex Fibers, Inc.
Front Royal, Virginia
EPA I.D. No. VAD 070358684

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INTRODUCTION

Section One

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1.0 INTRODUCTION

In 1985, Avtex Fibers, Inc., (Avtex), entered into an Administrative Order on Consent as the Potentially Responsible Party (PRP) to investigate the magnitude and extent of contamination of the environment, and to evaluate potential remedial action alternatives to correct the assessed environmental problems. Pursuant to the Order, Avtex, FMC, and its coordinating environmental consultant, Geraghty & Miller, Inc., (G&M) developed and submitted work plans for the performance of a PRP-directed Remedial Investigation/Feasibility Study (RI/FS). With approval of the workplans, Avtex and G&M initiated the data-gathering phase of the RI to determine the extent of ground-water contamination and to determine the chemical and physical characteristics of the most likely source of contamination, the viscose basins. The result of RI data collection and interpretation is to direct the FS as to media requiring corrective action and to allow the development of potential alternatives to mitigate continued contamination.

The Avtex, Front Royal, facility manufactures staple and filament rayon fiber. In the manufacturing process, two major chemical byproducts are generated and land disposed in on-site unlined surface impoundments. These byproducts are sodium cellulose xanthate-based viscose and zinc-hydroxide sludge (hereinafter referred to as "zinc sulfate sludge"). Up until 1983, the waste viscose was disposed in surface impoundments. Since then, the waste viscose has been piped directly to the facility waste-water treatment plant. The zinc-sulfate sludge is stored in specific basins for subsequent recovery, reprocessing, and reuse. The remaining major land-disposed item at the Front Royal facility is fly ash and boiler room solids.

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The practice of land disposing waste byproducts has been ongoing at the Front Royal facility since 1940. Since 1940, several corporate entities have controlled the Front Royal facility. From 1940 to 1963, American Viscose was the owner. From 1963 to 1976, FMC Corporation (FMC) was the corporate entity. Since 1976, Avtex has been the owner. The practice of land disposal has been drastically restricted during the ownership of Avtex.

Avtex has contracted for the performance of hydrogeologic studies in order to evaluate the source and extent of contamination which was reported to exist in domestic water-supply wells at the Rivermont Acres subdivision, located on the South Fork of the Shenandoah River across from the Avtex facility. Avtex and its contractors have completed this work in cooperation with representatives of the Virginia State Water Control Board and the Virginia Department of Health.

1.1 Purpose of Report

Although Avtex has presented information to EPA demonstrating that no threat to human health or the environment now exists, the U. S. Environmental Protection Agency (EPA) has placed the Avtex facility on the National Priorities List. Avtex and G&M have performed EPA-approved tasks in order to determine the existence, nature, and extent of any imminent and substantial endangerment to human health or the environment.

The objective of any remedial investigation would be to 1) identify contaminant source areas and hazardous constituents disposed therein, 2) define the extent of both surface and subsurface contamination from identified source areas, 3) provide adequate information to assess the environmental and health risk posed by such contamination, and

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4) provide sufficient information to conduct a feasibility study (FS) for evaluating, screening, and selecting a socially acceptable, cost-effective, technically manageable remedy.

1.2 Site Background and History

Avtex, a commercial rayon manufacturer, is located in Front Royal, Warren County, Virginia (Figure 1.1). Originally, the Front Royal facility was owned by American Viscose Corporation and, subsequently, by FMC. In 1976, Avtex purchased the assets of the FMC Fiber Division. The facility covers approximately 440 acres, with 60 acres under-roof. The facility has a total of 25 separate land-disposal structures that have historically or currently been used in the rayon manufacturing process (Figure 1.2 and Appendix A).

1.2.1 Review of Manufacturing Processes at the Front Royal Facility

The Avtex, Front Royal, facility has produced rayon, polyester, and polypropylene fibers. Rayon staple and filament fiber is the single product that has been manufactured since the conception of the facility in the 1940s as American Viscose. Polyester fiber was only manufactured between 1970 and 1977. Polypropylene fiber production commenced in January of 1985. Although the land-disposed waste products at the facility are from the rayon process, all three fiber-production techniques are summarized below.

1.2.1.1 Polypropylene

Avtex purchases bulk polypropylene chips which are melted in an extruder and pumped to a spinning unit. At this point, the liquid polypropylene is extruded through

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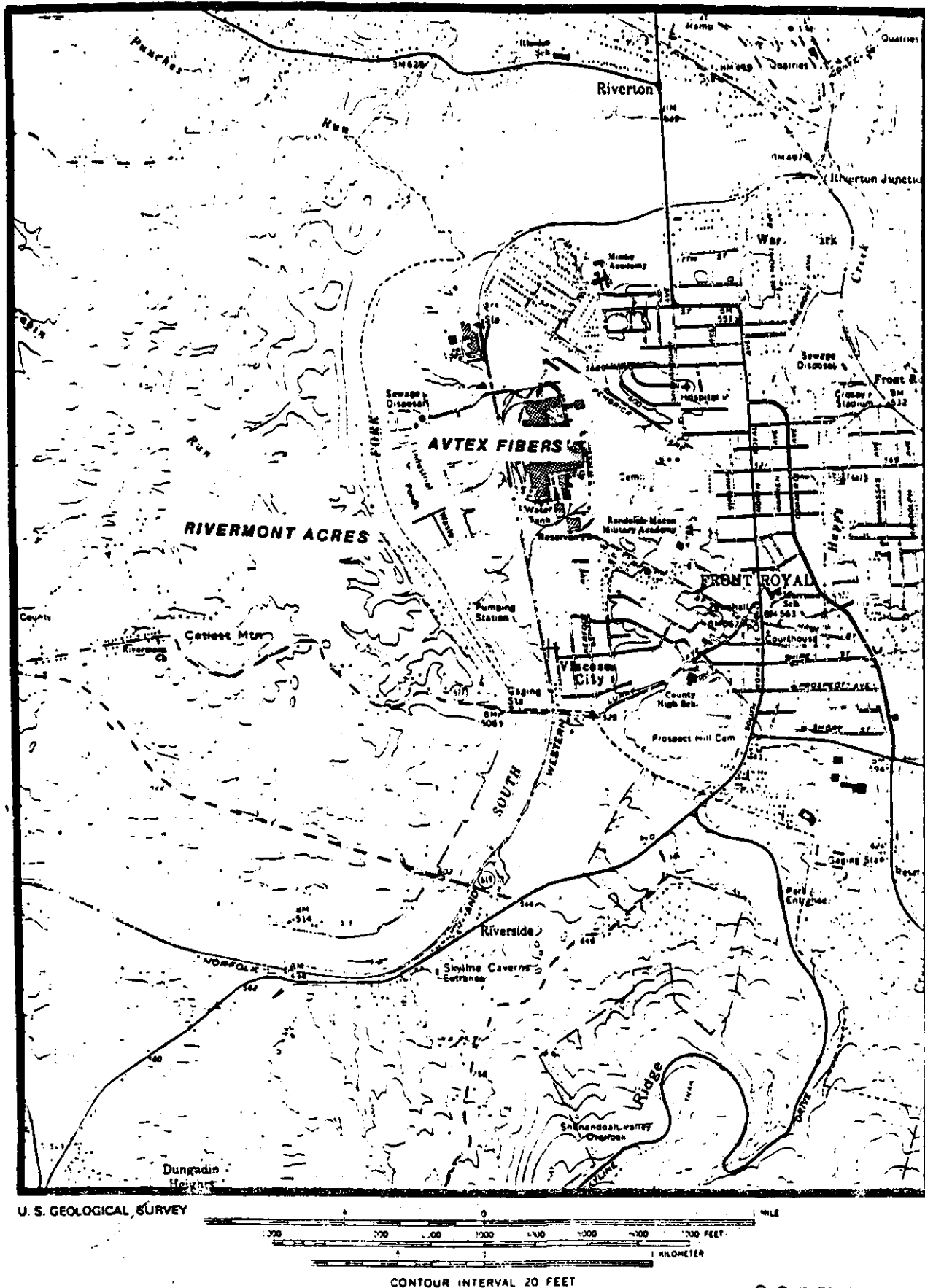


Figure 1.1 Location Map of the Avtex Fibers, Inc., Facility

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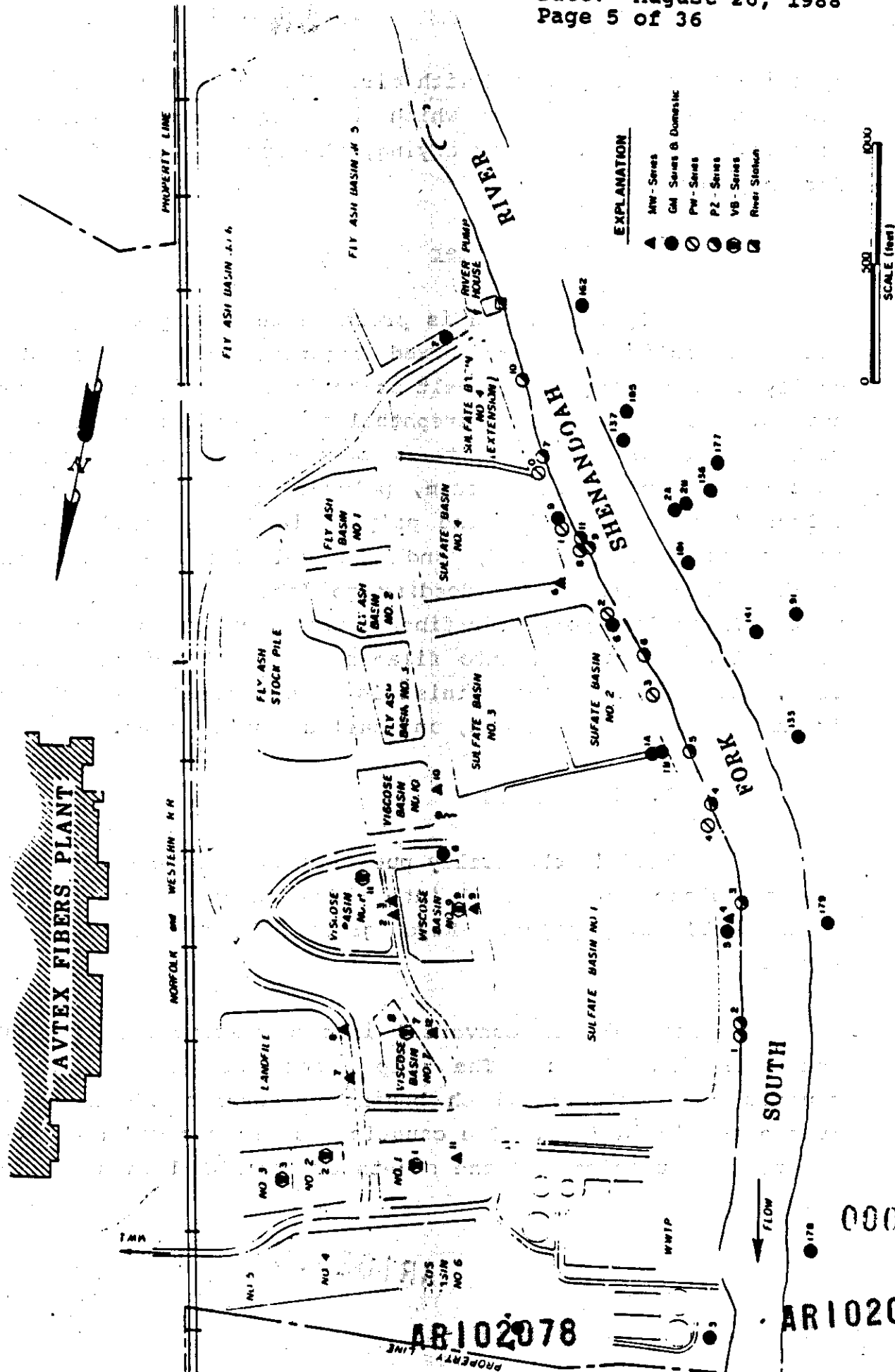


Figure 1.2 Locations of Avtex Land-Disposal Units

spinning jets and quenched with air. The resulting filaments are gathered into a tow which is heated and stretched, crimped, and dried. After drying, the tow is cut and baled for shipment.

1.2.1.2 Polyester

Polyester resin is produced when ethylene glycol and terephthalic acid are mixed together with appropriate catalysts and charged in a melt state into esterification reactors. Bishydroxethene terephthalate is formed and passed with additional catalysts to a multi-state polymerization unit where, under high vacuum, polymer forms and glycol is released and condensed. The polymer is then extruded from the reactor and chilled, and the solidified product is chopped into pellets for feeding to fiber producing equipment. To produce polyester fibers, the amorphous pellets are reheated and converted into filaments by melt spinning and, then, stretching. Fiber finish is then applied. The fiber is then crimped, dried, cut, and baled for shipment.

1.2.1.3 Rayon

Wood is chemically purified to produce cellulose. The cellulose is converted into white sheets of pulp that resemble blotting paper. Rayon-grade pulp is purchased by Avtex.

The pulp is converted into a viscose solution by the following steps: The pulp sheets are steeped in a caustic soda solution which begins conversion of the cellulose to liquid form. The caustic soda is removed from the sheets by squeezing and the sheets are crumbled in a shredder.

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After the crumbs are aged in a controlled temperature cellar, they are mixed in large mechanical churns with carbon disulfide to form an orange-colored crumb called xanthate. The cellulose xanthate is dissolved in caustic soda and the resulting solution, "viscose," is filtered to remove impurities and air bubbles. The viscose is thick and orange in color and is used to produce rayon in one of two forms: continuous filament or staple fiber.

In the continuous filament process, filaments are formed as viscose and pumped through jets into a sulfuric acid bath on the spinning machines. As the cellulose is regenerated, it is stretched. Zinc sulfate is added to the bath to retard regeneration and to increase the amount of orientation. Fibers having high strength and toughness are made in baths having relatively high zinc concentrations. The filament yarns are washed and purified. After drying, the filament yarn is processed into packages for shipment to customers and wound onto tubes.

In the staple process, the viscose is pumped through larger jets than those used in the continuous filament process. The resulting filaments are drawn together in parallel to form a continuous rope or tow. The rayon tow is cut into uniform lengths of one-fourth to seven inches before washing, processing, and drying. The rayon staple is similar in appearance to cotton and is shipped in bales.

1.2.2 Waste Land Disposal at the Front Royal Facility

In the production of man-made fibers, several waste products are generated and have been disposed in surface impoundments. These wastes have been predominantly viscose/liquid, solids and primary metal precipitate and waste-activated sludge. In addition, on-site disposal of fly

ash from the plant boiler room constitutes the third major material disposed in unlined surface impoundments.

1.2.2.1 Viscose Basins

A major liquid waste generated at the facility is waste viscose. This waste product is generated from; 1) backwashing of viscose filters that are used to remove undissolved cellulose particles; and 2) waste associated with the fiber-making process.

Prior to the 1976 acquisition of the facility by Avtex, waste viscose constituted the major byproduct disposed on site. Figure 1.2 and Appendix A are illustrations of the various impoundments on the Front Royal property. Eleven impoundments have been used for liquid waste viscose deposition since 1940. Viscose Basins 1 through 8 were used by American Viscose, while Basins 9, 10, and 11, were used by both American Viscose and FMC. Since the acquisition of the facility by Avtex in 1976, only Basins 9 and 11 have been used. Avtex has undertaken to recover for reuse a large proportion of off-specification viscose; this practice has greatly reduced the amount of waste viscose which is treated or disposed. Since 1983, land disposal of liquid waste viscose has been discontinued and discharged directly to the on-site waste-water treatment plant. The volumes of viscose disposed, the responsible corporate entities, basin identifications, and current situation, are presented in Table 1.1.

Of the 14,450,000 cubic feet of waste viscose disposed in the on-site impoundments, 41 percent is attributed to American Viscose, 47 percent to FMC, and only 12 percent to Avtex.

TABLE 1.1
 LIQUID WASTE VISCOSE DISPOSAL AT FRONT ROYAL

Time Period	Basin	Volume of Viscose Disposal (ft ³)	Corporate Entity	Current Status
1940*	1	300,000	American Viscose	Closed and covered
1942*	2	380,000	American Viscose	Closed and covered
1943*	3	400,000	American Viscose	Closed and covered
1944*	4	400,000	American Viscose	Currently draining and treating liquid volume
1945*	5	590,000	American Viscose	Currently draining and treating liquid volume
1946-1950	6	1,480,000	American Viscose	Currently draining and treating liquid volume
1950-1958	7&8	1,140,000	American Viscose	Closed and covered
1958-1983	9	3,270,000	American Viscose FMC, Avtex	Currently draining and treating liquid volume
1961-1972	10	3,830,000	FMC	90 percent of liquid volume has been removed
1974-1983	11	2,720,000	FMC & Avtex	Currently draining and treating liquid volume
Total Volume = 14,390,000 cubic feet				

*Date is the given year of construction. The construction of a subsequent basin is assumed to be the time frame of each basin use.

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1.2.2.2 Sulfate Basin

An integral part of the waste-treatment system and facility operation is an extensive network of unlined sulfate basins that cover approximately 85 acres and have been in use for approximately 40 years. The sulfate basins receive sludge generated from the primary clarifiers and polishing basins of the on-site waste-water treatment plant (WWTP) with No. 1 sulfate basin currently the only one receiving process water. Activated sludge from secondary treatment is also transferred to the sulfate basins after undergoing stabilization in an aerobic digester. The sulfate basins also receive process water if the WWTP is hydraulically or organically overloaded.

The sulfate basins contain approximately 1200 acre-feet of sludge having 80 million pounds of zinc. The sludge is mined for the high concentrations of zinc which is an essential ingredient in rayon processing. These basins serve as repositories for zinc reclaimed as zinc sulfate.

1.2.2.3 Fly Ash Basins

Several basins have been used for the disposal of fly-ash and boiler house solids. In addition, a stabilized fly ash pile exists northeast of Ash Retention Basin 3. Ash Retention Basins 1, 2, and 3, are no longer used for disposal. Currently, all fly ash is sluiced via pipeline to Ash Retention Basin 6. In addition, Sulfate Basin 5 may be retrofitted with a bottom liner for future fly-ash disposal. Ash Basins 1 and 2 are being excavated for additional short-term storage until Basin 5 is retrofitted.

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1.2.2.4 Former Landfill

Until 1983, solid waste from the manufacturing process was disposed in a landfill built on Viscose Basins 4, 5, and 6. Solid wastes were used to fill and cover the viscose basins. The area is presently in a closure process with liquid dewatering, cover grading, contouring, capping, and hydroseeding. The currently generated solid waste is received at the new landfill located directly south of Viscose Basins 2 and 3.

1.2.2.5 New Landfill

Since late 1983, solid process wastes have been received at the new landfill operating under Virginia Permit No. 357. This landfill has multiple cells with liners and leachate collection systems tied directly to the on-site WTP.

1.2.3 Waste Water and Waste Handling Processes and Treatment

The Avtex plant sewers containing acid waste, sulfide waste, and alkaline wastes, are combined in a neutralizing basin where pH is adjusted from 2.5 to near 9.0 by adding lime slurry. The zinc sulfate in the waste stream reacts with the lime to form zinc hydroxide precipitate. The 11-mgd flow is split to two clarifiers where solids settle. The clarifier underflows are pumped to the sulfate basins, while the overflow continues to two polishing basins where additional clarification occurs. Up to 99 percent of the zinc is removed by this point. The zinc in the sulfate basin is subsequently mined and converted to zinc sulfate for plant use.

From the polishing basins, the waste stream enters the conventional activated sludge secondary treatment plant. The plant includes two aeration chambers operated in parallel. The aerated waste overflows to the two final clarifiers where the underflow is routed to a sludge thickener and digester. The clarifier overflow is then discharged to the South Fork of the Shenandoah with a pH between 6.5 and 9.5. The discharge is controlled by NPDES Permit Number 0002208.

Bioassay tests with fathead minnows and daphnia have shown that acute toxicity is removed by the treatment process. Chemical oxygen demand (COD) removal is approximately 80 percent, and no carbon disulfide is detectable in the finished water.

The facility's waste water is handled and discharged through four outfalls. Outfalls 001 and 002 receive waste water from the fly-ash retention basins and stockpile. Outfall 003 is the storm-sewer discharge that primarily receives cooling water from various systems and waste-water softeners. Outfall 004 handles the various process waste waters treated by the WWTP.

1.2.4 Chemical Characteristics of Land-Disposed Waste

As explained in Section 1.2.2, the major process-waste byproducts which have been handled by on-site land-disposal structures are:

- . fly ash
- . liquid waste viscose
- . primary metal precipitate

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1.2.4.1 Fly Ash

Presently, the fly-ash solids and grains are sluiced to Disposal Basin 6, where water is decanted and discharged through NPDES Permit VA 0002208 Discharge No. 001. The chemical character of the decanted water is presented in Table 1.2

The chemical characteristics of the fly-ash solids have been developed from the analysis of a grab sample. In accordance with the E.P. toxicity procedures described in the Federal Register - May 19, 1980, the metal extractions from the fly-ash sample were all within the maximum limits set forth by the State of Virginia, Hazardous Waste Management Regulations - Section 3.10.03. The E.P. Toxicity (EP TOX) analysis is presented as Table 1.3.

1.2.4.2 Viscose Basins

Several of the viscose basins have been closed and covered for many years, and little knowledge of the chemical characteristics of the impounded material is known. However, the rayon process has had limited technological changes over the past 40 years. It is assumed that the contents of Basins 1, 2, 3, 7, and 8, are similar in chemical makeup to the contents of the more recently used Basins 9 and 11. With continued liquid dewatering of Viscose Basins 4, 5, 6, 9, 10 and 11, more data on the chemical constituents of these basins, and a better understanding of the chemical transformation of viscose with age, shall be developed. Pre-CERCLA analytical results for liquid samples obtained from Viscose Basins 5, 6, and 11, are presented as Tables 1.4 and 1.5. In addition, EP Tox was performed on material from Viscose Basin 11. This data is presented as Table 1.6. The

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CONTINUE ON PAGE V-2

CHEMICAL CHARACTER OF THE DECANTED WATER

CONTINUED FROM PAGE 3 OF FORM 3C

EPA I.D. NUMBER (cont) from Item 1 of Form 1: OUTFALL NUMBER
 VA 0070358684 001

Rev. No. 3, December 20, 1981
 Form Approved OMB No. 168-R0173

PART C. If you are a primary industry and this outfall contains process wastewater, refer to Table 2c-2 in the instructions to determine which of the GC/MS fractions you must test for. Mark "X" in column 2-a for all such GC/MS fractions that apply to your industry and for ALL toxic metals, cyanides, and total phenols. If you are not required to mark column 2-a (secondary industries, non-process wastewater outfalls, and non-required GC/MS fractions), mark "X" in column 2-b for each pollutant you know or have reason to believe is present. Mark "X" in column 2-c for each pollutant you believe to be absent. If you mark either column 2-a or 2-b for any pollutant, you must provide the results of at least one analysis for that pollutant. Note that there are seven pages to this part; please review each carefully. Complete one table (all seven pages) for each outfall. See instructions for additional details and requirements.

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X" (a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (l) (m) (n) (o) (p) (q) (r) (s) (t) (u) (v) (w) (x) (y) (z)	3. EFFLUENT				4. UNITS		5. INTAKE (optional)			
		A. MAXIMUM DAILY VALUE (mg/L)	B. MAXIMUM 30 DAY VALUE (mg/L)	C. MAXIMUM 30 DAY VALUE (mg/L)	D. MAXIMUM 30 DAY VALUE (mg/L)	A. CONCENTRATION	B. MASS	A. LONG TERM AVERAGE VALUE (mg/L)	B. NO. OF ANALYSES		
METALS, CYANIDE, AND TOTAL PHENOLS											
1M. Arsenic, Total (1740-38-6)	X	0.022					mg/L	lbs./day	0.001	0.004	1
2M. Arsenic, Total (1740-38-6)	X	0.02	0.12				mg/L	lbs./day	0.008	0.035	5
3M. Beryllium, Total (1740-41-7)	X	< 0.0002					mg/L	lbs./day			NA
4M. Cadmium, Total (1740-43-9)	X	0.0083					mg/L	lbs./day			NA
5M. Chromium, Total (1740-47-3)	X	0.03	0.12				mg/L	lbs./day	0.012	0.052	4
6M. Copper, Total (1740-48-4)	X	0.01	0.06				mg/L	lbs./day	0.053	0.229	27
7M. Lead, Total (1740-37-4)	X	0.03	0.18	0.03	0.18		mg/L	lbs./day	0.222	0.960	4
8M. Mercury, Total (1740-37-4)	X	< 0.0002					mg/L	lbs./day			NA
9M. Nickel, Total (1740-32-4)	X	0.08	0.48				mg/L	lbs./day			NA
10M. Selenium, Total (1740-32-4)	X	< 0.002					mg/L	lbs./day	0.003	0.013	1
11M. Silver, Total (1740-32-4)	X	< 0.0002					mg/L	lbs./day	0.001	0.004	1
12M. Thallium, Total (1740-28-4)	X	< 0.001					mg/L	lbs./day	0.001	0.004	1
13M. Zinc, Total (1740-30-6)	X	0.11	0.66	0.03	0.18		mg/L	lbs./day	0.01	0.043	24
14M. Cyanides, Total (1740-32-4)	X						mg/L	lbs./day			NA
15M. Phenols, Total	X	See V-5	10A				mg/L	lbs./day	0.026	0.0112	1
DIOXIN											
16M. Total Dioxin (1740-32-4)	X										

DECEMBER 20, 1981

EPA Form 3510-3C (8-80)

TABLE 1.2. CHEMICAL CHARACTER OF THE DECANTED WATER (CONT.)

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TABLE 1.3
E.P. TOXICITY OF LAND-DISPOSED FLY ASH

Metal	Extract (mg/l)	E.P. Tox Limit Maximum (mg/l)*	Analysis Notations
Arsenic	0.064	5.0	VPI AA-furnace
Cadmium	0.002	1.0	VPI AA-furnace
Chromium (VI)	0.005	5.0	Commonwealth Lab EPA/APHA
Copper	0.075	-	VPI AA-furnace
Iron	0.010	-	Avtex AA-flame
Lead	0.020	5.0	VPI AA-furnace
Manganese	0.010	-	Avtex AA-flame
Mercury	0.002	0.2	Commonwealth Lab EPA/APHA
Nickel	0.142	-	VPI AA-furnace
Selenium	0.007	1.0	VPI AA-furnace
Zinc	0.020	-	Avtex AA-flame

*State of Virginia Hazardous Waste Management Regulations
Section 3.10.03.

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TABLE 1.4
VISCOSE BASIN LIQUID ANALYSIS FROM NOS. 5 AND 6+

Parameter (mg/l)	Basin 5	Basin 6
Chloride	4,870	2,297
Sulfate	3,000	4,000
Alkalinity	29,181	10,449
TDS	47,108	18,014
TKN	1.4	2.1
Sulfide	932	291
Phenolics	5.8	1.0
TOC	2,350	540
Arsenic	0.3	0.1
Zinc	0.2	0.3
Sodium	16,100	5,600
Manganese	0.1	<0.1
COD	7,220	3,550
TSS	796	65
TVSS	150	40
CS ₂	<100*	<100*

+ January 1984 Analysis

* Measurements is in ug/l

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TABLE 1.5
NO. 11 VISCOSE BASIN ANALYSIS

	June, 1984	1983 Composite Analysis
pH*	-	12.0
Total Solids	63,478	194,500
Volatile Solids	6,556	88,400
Alkalinity as CaCO ₃	45,000	31,718
Sulfide	2,574	1,834
Sulfate	2,600	308
Chlorides	6,000	4,732
Total Phenols	2.01	0.13
COD	6,580	11,500
TOC	1,730	5,712
CS ₂	-	46.15
Na	22,000	18,300
Zn	5.1	30
Nitrate as N	<50	-
As	0.40	<0.01

All results reported in mg/kg except *.

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TABLE 1.6
E.P. TOXICITY RESULTS ON MATERIAL
FROM VISCOSE BASIN NO. 11

Parameter	Concentration (mg/l)	EP TOX Standard*
Arsenic	0.0038	5.0
Selenium	0.0020	1.0
Lead	0.0500	5.0
Cadmium	0.0030	1.0
Hexavalent Chromium	0.0050	5.0
Mercury	0.0020	0.2

*The extraction was done according to E.P. Toxicity Procedure described in Federal Register Vol. 45, No. 98, May 19, 1980, by Avtex Fibers, Inc. The metal analysis was performed by Commonwealth Laboratory following EPA approved methods.

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extractable values for the analyzed metals are all below the limits for EPTOX.

1.2.4.3 Sulfate Basins

The five sulfate basins are currently used as repositories for zinc sulfate for ongoing reclaim. Decanted fluids are gravity-fed from one sulfate basin to the next in a northern progression. Once the fluid reaches the emergency retention lagoon, it is fed into the first chamber of the WWTP for treatment and ultimate discharge. The zinc sludge in the bottom of each sulfate basin is mined and piped to the zinc recovery plant. Approximately 65 percent of the zinc is removed in the process, with the remaining 35 percent returned to the sulfate basins as zinc cake. An analysis of the contents of Sulfate Basin No. 1 is presented in Table 1.7.

1.2.5 Previous Investigations

Until 1983, the waste viscose was disposed of in basins located southwest of the Norfolk & Western railroad easement. Viscose Basins 1 through 8 were used prior to 1960; and, Basins 9, 10, and 11, were used until 1983. Avtex began to review its waste-generation practices and disposal basins in 1978. A synopsis of the environmental investigations and actions that have occurred at the Avtex Front Royal plant is presented in Appendix B.

The Virginia State Water Control Board (SWCB) requested that Avtex prepare and perform a ground-water investigation due to the 1982 discovery of carbon disulfide (CS_2) in ground-water samples from several wells across the Shenandoah River at Rivermont Acres. G&M was retained by Avtex in February 1983 to perform the investigation. The

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TABLE 1.7
NO. 1 SULFATE BASIN ANALYSIS

Parameter	Concentration*
pH	9.3
Solids	403,700
Volatile Solids	96,700
Sodium	2,300
Zinc	35,170
Alkalinity	68,330
Sulfide	1,986
Chlorides	1,235
Total Phenol	0.35
TOC	5,794
COD	31,600
Cadmium	2.1
Lead	29.0
Arsenic	5-
Selenium	5-
CS ₂	0.002
SO ₄	36,865

*Results are expressed as mg/kg, except for pH.

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overall objectives of the investigation were to determine if ground-water contamination had occurred, if it was related to the Avtex waste-disposal activities, and what feasible remedial methods were available.

Over the course of a phased field program, G&M installed numerous bedrock monitor wells, including two 2-well clusters on either side of the Shenandoah. Most of these wells were sampled and analyzed for contamination indicator parameters; aquifer tests were conducted to determine Martinsburg Formation hydraulics.

The Phase I investigation involved the evaluation of existing monitor-well data, geologic logs, and regional hydrogeologic reports, to determine the ground-water flow regime and the potential for contaminants to migrate across a suggested ground-water divide - the South Fork of the Shenandoah River.

The Phase IIA investigation consisted of sampling selected domestic wells in the Rivermont Acres Subdivision for key contamination indicator parameters. Samples collected were split with SWCB for analyses by their own laboratory. Phase IIB was designed to characterize the local ground-water flow system, and the extent of contamination within the Martinsburg Shale, by drilling wells on both sides of the river. In addition, a preliminary analysis of viable interim remedial measures was performed.

The Phase III investigation was designed to further characterize the flow system within the upper 150 feet of the Martinsburg Shale, and to install, test, and operate a three-recovery-well network placed within the three major identified fracture zones. Conclusions presented in the Phase IIB and III reports are based on several ground-

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water sample collection rounds, installation of shallow and deep bedrock wells, and on numerous short- and long-term pumping tests performed on both sides of the river.

For the Phase IIB investigation, multi-interval borehole tests were performed on Rivermont Acres domestic Wells 193-, 177-, 181-, and 286- prior to Avtex purchase. Nitrogen inflatable packers and a submersible pump were fixed at various depth intervals within the wells, and ground-water samples collected and analyzed for indicator parameters. In addition, 13 four-inch diameter observation wells were installed to depths ranging from 100 to 175 feet. Two six-inch diameter wells were installed along the facility perimeter berm within the area of highest yield and poorest ground-water quality. Subsequently, a 50-hour pumping test was performed on Well PW-2, with manual and automatic records kept on surrounding observation wells. A second round of ground-water sample was collected from selected domestic and monitor wells. The final Phase IIB task was to set up air-lift systems and surface-transmission pipes on PW-1 and PW-2 to pump contaminated ground water to Sulfate Basin No. 1.

The Phase III investigation involved drilling additional wells for recovery centers (PW-0, 3, and 4), redeveloping PW-1, -2, and -3, and short-term pumping tests, and ground-water sample collection from selected domestic wells at Rivermont Acres.

The results of Phase IIB and III investigations are:

- . Hydraulic connection exists between the east and west banks of the Shenandoah River, at least on a seasonal basis
- . A major fracture or fracture system extends from the vicinity of Vis se Basins 9, 10, and 11, southwest, across the river to Wells 177 and 181

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- . Ground water is controlled by bedding plane fracture systems, with regional flow along geologic strike to the southwest
- . Degradation of the Martinsburg Formation ground water extends vertically to at least 175 feet below land surface
- . Some shallow circulation of degraded fluids to the Shenandoah River is probably occurring; however, the surface-water sampling survey conducted showed only elevated levels for sulfate
- . The presence of contaminants along the Rivermont Acres floodplain may be attributable to specific waste-fluid characteristics and aquifer stress imposed by domestic well use over time at the subdivision.

1.2.6 Immediate Response Actions

As a result of the field investigation, Avtex initiated interim remedial measures. This includes the purchase of most of the Rivermont Acres subdivision, including those regions where little or no ground-water degradation was evidenced. In addition, Avtex initiated remedial measures to control degraded fluids from continuing to migrate off site. G&M installed three six-inch diameter recovery wells (PW-1, PW-2, PW-3) along the perimeter berm in the zone of ground-water degradation during 1984 for the purposes of contaminant recovery and containment. Ground-water pumping commenced in March, 1984, with the recovered fluids transferred to Sulfate Basin 1, for ultimate treatment.

Maintenance problems have caused the pumping wells to be turned off periodically for servicing. Mixing of waters within the borehole has lowered pH, causing silica to precipitate on the borehole wall, thereby reducing permeability.

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Since Avtex purchased all homes with domestic wells within the degraded area, no aquifer stress by pumping of domestic wells is occurring. In addition to ground-water counterpumping, Avtex has dewatered Viscose Basin 10 by 90 percent and is in the process of dewatering Viscose Basins 9 and 11. Several pits have been excavated along the perimeter of each basin down into the standing liquid. Pumps have been installed in the pits; and, waste liquids are removed and piped to the WWTP. The process of basin dewatering, as an interim remedial measure, reduces the hydraulic head within the basins, thus, reducing the vertical gradient to the underlying Martinsburg Formation.

1.3 Overview of Physical Site Conditions

1.3.1 Climatology

Front Royal, Virginia, sits at the base of Dickey Ridge and, as such, is subject to rapid weather changes. Front Royal has an average annual precipitation of 38 inches. The average annual temperature is 55.2°F. Table 1.8 is a compilation of average monthly rainfall and temperature data for the period 1931-1960 (NOAA, 1974).

1.3.2 Regional Physiographic/Geologic Setting

Front Royal, Virginia, is located along the boundary of the Valley and Ridge, and Blue Ridge physiographic provinces. These provinces are characterized by distinct relief features, landforms, and geologic structures, attributable to periods of movement of the earth's crust. The geologic units in the Front Royal area have been deformed into complex structural features as a result of the crustal movement which forced older rocks of Pre-Cambrian age over

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TABLE 1.8
TEMPERATURE AND PRECIPITATION DATA FOR THE
FRONT ROYAL AREA

Month	Temperature(F)	Precipitation(inch)
January	34.9	2.39
February	36.1	2.12
March	43.0	3.16
April	54.2	3.11
May	64.3	4.10
June	72.2	3.70
July	76.1	4.24
August	74.5	4.16
September	68.0	2.97
October	57.3	3.45
November	46.0	2.59
December	36.2	2.48

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younger rocks of Cambrian/Ordovician age (Rader and Biggs, 1976).

1.3.3 Geology

As a result of this crustal movement, the sedimentary sequences in the vicinity of the South Fork of the Shenandoah River buckled into a series of near-parallel ridges and valleys (anticlines and synclines). The stress imposed on the geologic units caused major and minor crustal fractures and fault zones. These fractures and faults control the movement and occurrence of ground water (Cady, 1936).

The sedimentary Valley and Ridge units in Front Royal are illustrated in Tables 1.9 and 1.10 and Figure 1.3. Additionally, subsequent erosion of material from the highlands was carried by intermittent and perennial streams to the low-lying areas where they accumulated as alluvial fill, and bank and terrace deposits, such as the surficial deposits surrounding the North and South Forks of Shenandoah River (Rader and Biggs, 1975).

1.3.4 Hydrology

Ground water occurs in all rock types, including the sedimentary rocks like those of the Valley and Ridge Province. These sandstones, limestones, and shales are, in general, moderately permeable, partly as a result of the available space between the particle grains. Ground water in sedimentary units migrates along tortuous paths between these particles. The ease with which ground water flows within these voids is a function of the properties of the migrating fluid and the shape and degree of interconnection of the pore spaces.

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TABLE 1.9
SEDIMENTARY FORMATIONS IN THE FRONT ROYAL AREA

<u>Geologic Unit</u>	<u>Description</u>
Martinsburg Formation	Interbedded green to gray shales, gray sandstone, black silty shale, and black limestone
Oranda/Edinburgh Formation	Siltstone, black fissile shales, and microcrystalline limestone
Lincolnshire/New Market Formation	Gray, fine-grained limestone to bioclastic limestone and carbonate-pebble conglomerate
Rockdale Run Formation	Fine-grained limestone to dolomitic limestone
Conococheague Formation	Interbedded limestones and laminated dolomites

Source: Rader, E.K. and Biggs, T.H., 1975

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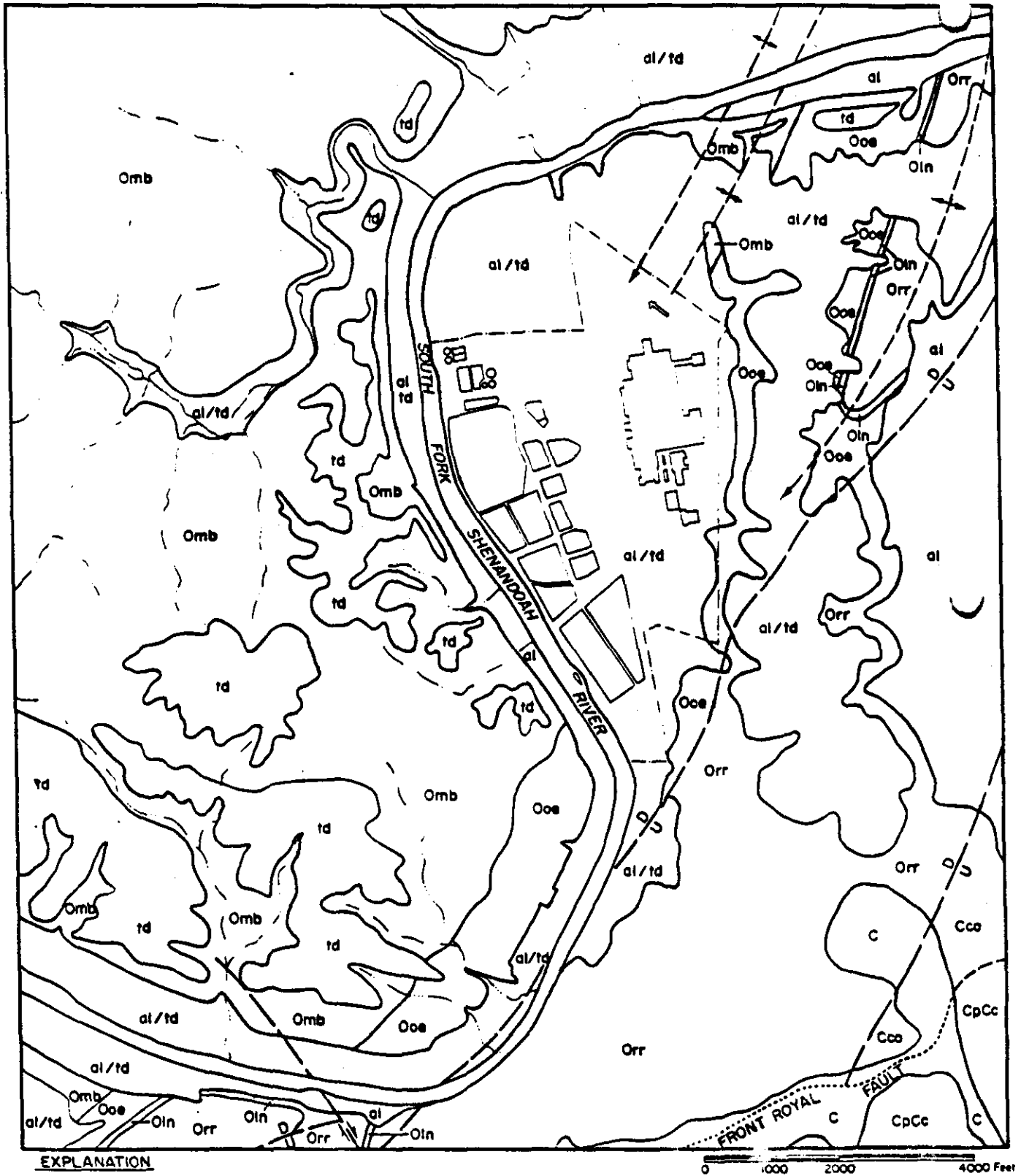
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TABLE 1.10
SYMBOL REFERENCE FOR GEOLOGIC UNITS IN
FRONT ROYAL AREA

<u>Symbol</u>	<u>Geologic Unit</u>
al	Alluvium
td	Terrace Deposits
Omb	Martinsburg Fm
Ooe	Oranda and Edinburg Fms.
Orr	Rockdale Run Fm.
Oln	Lincolnshire Fm. and New Market Limestone
C	Colluvium
Cco	Conococheague Fm.
CpCc	Catoctin

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EXPLANATION

FOLDS

- +— Anticline - Trace of fold and direction of plunge
- Syncline - Trace of fold and direction of plunge

FAULTS

- D— Downthrown side
- U— Upthrown side
- >—>—> Arrows indicate direction of relative movement

FOR DESCRIPTION OF GEOLOGIC FORMATIONS, SEE TABLE 9

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Figure 1.3 Geologic Map of Front Royal, Virginia

Where sedimentary sequences are deformed into complex geologic structures, fractures may become the primary conduits for ground-water migration, and fluids will preferentially flow in these fractures. Field investigations performed by G&M at the Avtex facility from 1983 to 1985, as well as analyses of aquifer tests, verified the importance of fractures on the migration and presence of ground water within the Martinsburg Formation (Geraghty & Miller, Inc., 1984 and 1985).

1.3.5 Facility Hydrogeology

1.3.5.1 Geology

The Avtex, Front Royal, facility is located on river alluvial deposits of sand, silt, clay, and meta-igneous cobbles. These surficial deposits are approximately 20- to 30-feet thick, as recorded from the installation of on-site monitor wells. The river deposits are underlain by the Martinsburg Formation. Locally, the formation consists of massive and fractured greenish-gray shale with occasional void spaces and stringers of silty sandstone. In general, the attitude of the formation beds is nearly vertical, with geologic strike trending northeast-southwest. The structural attitude of the beds is clearly visible as the river bottom of the South Fork of the Shenandoah River. The thickness of the formation locally is unknown due to its structural deformation. Greater detail on local geologic conditions is presented in the G&M reports presented as Appendices B and C.

1.3.6 Hydrology

Locally, the ground-water flow system is complicated by the presence of major fracture zones within the Martinsburg Formation. Numerous bedrock wells, installed

during the 1983-85 field studies (Figure 1.4), yielded highly variable specific capacities. Based on aquifer tests during January 1984 and January 1985, ground water within the Martinsburg Formation is controlled by major fracture zones which are parallel to the structural strike of the shale bedrock. The degree and speed to which water levels responded to pumping indicate that the rock mass, as a whole, has low permeability; and, the foremost mechanism of ground-water flow is due to this secondary permeability. In addition, the pumping caused drawdown in domestic wells at Rivermont Acres, located across the Shenandoah River from the facility. Monitor wells within the alluvial deposits showed no influence to pumping. This phenomena indicates that at least the ground water within the upper confines of the Martinsburg Shale and the overlying alluvial deposits discharges to the Shenandoah River.

Comparison of head values from monitor wells within the bedrock and overlying alluvial deposits suggests a downward component of ground-water flow at the site. This phenomena is probably increased by the dynamic head of fluids impounded in the various facility basins.

Regionally, the meandering South Fork of the Shenandoah River represents the regional ground-water and surface-water discharge point. The Shenandoah flows to the northeast where it joins with the Potomac River.

1.3.7 Ground-Water Use in the Vicinity of the Front Royal Facility

The City of Front Royal and various outlying subdivisions northeast, east, and southeast of the Avtex facility rely upon the Shenandoah River for water supply. Residences west of the South Fork of the Shenandoah River

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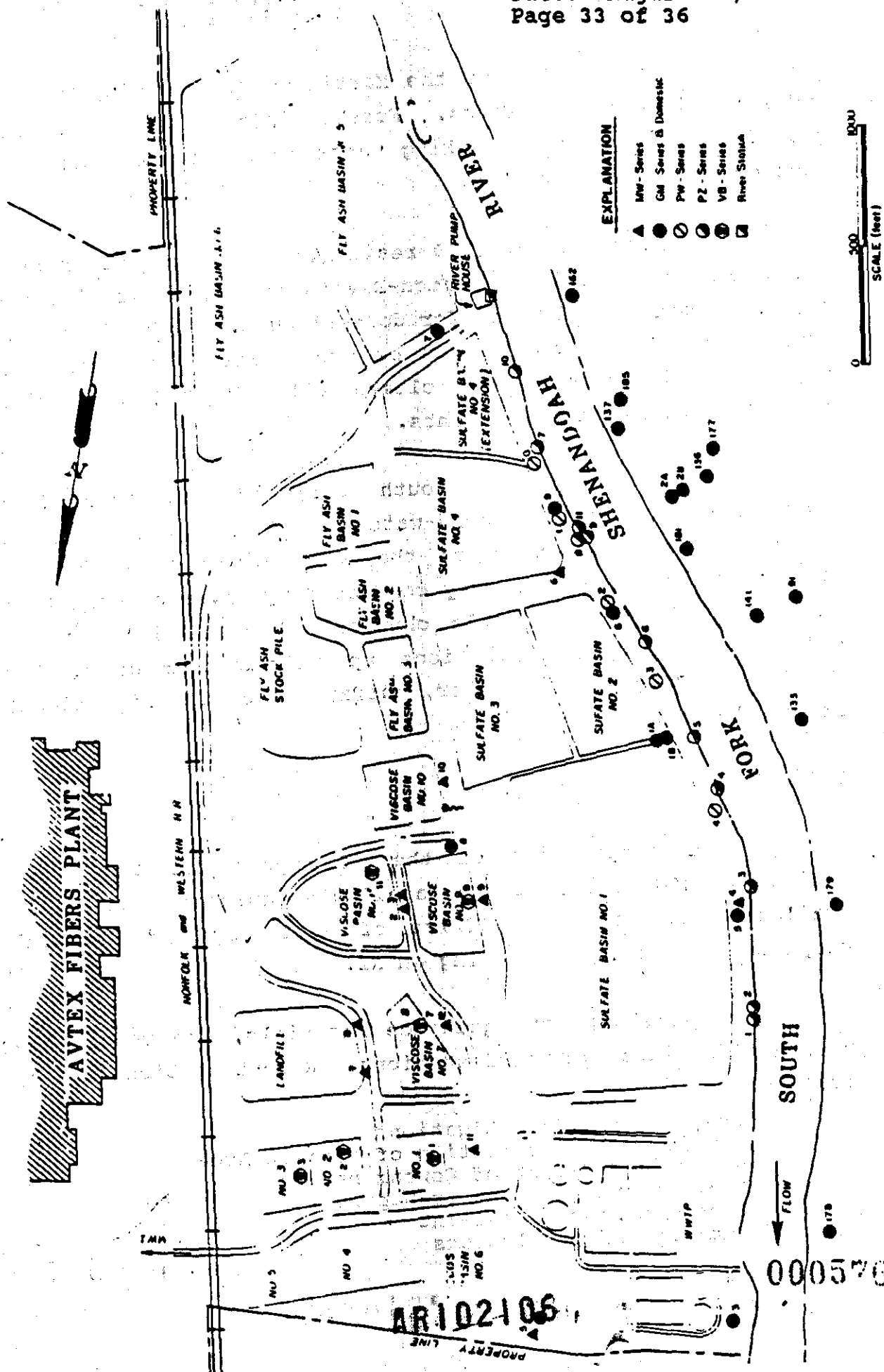


Figure 1.4. Location of Monitoring Well Network at the Avtex Facility

rely upon ground water of the Martinsburg, Edinburg-Oranda, and Rockdale Run Formations. Further information concerning ground-water use as a drinking water source is presented in Section 3.0 of this report.

Prior to 1983, 19 residents across the river from Avtex in the Fiddler's Green-Rivermont Acres subdivision depended upon ground water for domestic use. With subsequent evaluation of varying degrees of ground-water contamination in the subdivision, Avtex closed all affected wells and relocated most of the residents.

Although the South Fork of the Shenandoah represents the local ground-water discharge point for at least the upper section of the Martinsburg Formation, a surface-water chemical survey conducted by Environmental Labs for Avtex showed negligible chemical changes in the water column from sampling locations up and downstream of the facility. Only the parameter, sulfate, showed a significant change downstream.

1.4 Report Organization

In the preparation of the RI report for the Avtex facility, G&M referred to available guidance materials available from the EPA Office of Emergency and Remedial Response concerning conducting an RI.

In keeping with the guidance materials, the report has been divided into six major sections. Report sections are as follows:

- Project Area Investigations
- Physical Characteristics of Project Area
- Nature and Extent of Contamination
- Contaminant Fate and Transport
- Baseline Risk Assessment
- Summary and Conclusions

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Section 2.0 Project Area Investigation details the individual tasks performed as part of the RI including equipment and procedures used. Individual tasks covered include:

- Surface Geophysical Surveys
- Ground-Water Sampling
- Bedrock Drilling
- Near-Source Well Installation
- Source Investigation
- Aquifer Testing

Section 3.0 Physical Characteristics of the Project Area presents the results of each RI task as well as tasks performed prior to the initiation of CERCLA action which bear heavily on the environmental assessment.

Section 4.0 Nature and Extent of Contamination presents information concerning source areas, magnitude of ground-water contamination and chemical constituents of concern.

Section 5.0 Contaminant Fate and Transport discusses factors pertaining to the contaminants and source areas which have led to the migration of pollutants in the ground-water system.

Section 6.0 Baseline Risk Assessment presents information and conclusions regarding potential pathways of exposure, contaminants of concern, and risk characterization with regard to public health and welfare.

Section 7.0 Summary and Conclusions details the major findings of the RI and reiterates important information to be incorporated into the FS.

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GERAGHTY & MILLER, INC.

Section No.: 1.0
Revision No.: 1
Date: August 26, 1988
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For reader ease, extensive field data sheets are presented as appendices to reduce the volume of exhibits within the actual text. In addition, previous investigations performed prior to CERCLA activity which have been used as part of the RI development are presented as appendices.

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PROJECT AREA INVESTIGATION

Section Two

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2.0 PROJECT AREA INVESTIGATION

With approval of the RI/FS work plans in April 1987, G&M initiated field tasks at the Avtex facility within 30 days of the approval date. The order of investigative activities was 1) surface geophysics, 2) ground-water sampling-round 1, 3) riverbank well installation, 4) viscose basin perimeter well installation, 5) viscose basin boring program, and 6) aquifer testing program.

In each case, project coordination involved project team meetings prior to the installation of each task in order to familiarize each individual with task procedures and health and safety considerations. For the tasks involving multiple people, a full-time team leader was selected. As the project continued, especially during the drilling phase of work, a full-time health and safety representative was placed on site. This individual was responsible for monitoring ambient air quality with respect to hydrogen sulfide and carbon disulfide vapors, and for selecting an adequate level of protection for the drilling crew, sampling team, and field geologist.

Section 2.0 presents information concerning the logistics of each field activity and information pertinent to the evaluation of the physical characteristics of the project area. Each particular field task is discussed below.

2.1 Surface Geophysical Surveys

During May 1987, G&M conducted two separate surface geophysical investigations at the Avtex facility to define specific subsurface features. These investigations included a dipole-dipole arranged resistivity profile of the shallow

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bedrock, and a shallow electromagnetic summary in and around the viscose basins.

2.1.1 Resistivity Survey

An electrical resistivity survey was conducted along several lengthy transects located along the river perimeter berm at Avtex and along the floodplain at Rivermont Acres. In addition, shorter transects were performed along the north side of Viscose Basins 4, 5, and 6, and up the narrow ravine near Well 193-177 at Rivermont Acres.

The field methodologies employed, as well as the survey results, have been previously submitted to the Agency. The report for the electrical resistivity survey is presented as Appendix C.

2.1.2 Electromagnetic Survey

A shallow-penetrating, fixed-frequency electromagnetic survey was performed in and around the viscose basins to determine the boundaries of the closed basins, and to evaluate the presence of highly mineralized fluids extending entirely beyond the boundaries of open and closed basins.

Apparent conductivity data were collected over a total of 19 separate survey lines. Each of the survey lines was laid out using a Brunton packet transit and a nylon measuring tape. At 100-foot intervals along each line, a reference station was established using fluorescent organic pine flags.

Each survey line was traversed twice, once with the EM-31 oriented horizontal coplanar and once with the EM-31 oriented vertical coplanar. To provide a continuous record of the apparent conductivity being measured across each

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traverse, the EM-31 was coupled to an analog chart recorder. As the instrument passed each of the reference stations, the chart record was annotated to facilitate correlation between the data record and locations in the field. Copies of the apparent conductivity profiles are provided in Appendix D.

2.2 Ground-Water Sampling and Analysis

During the course of the Remedial Investigation, two rounds of ground-water samples were collected. The first sampling round was conducted during May and June 1987, prior to the installation of the PZ and VB-monitor-well series. Samples were collected from the existing PW, GM, MW, and the Rivermont Acres domestic well series. A second complete round of samples was collected after the new monitor-well series was installed. The second round of ground-water sampling was performed during August 1987. The viscose basin piezometers were sampled during September 1987. In accordance with the Sampling and Analysis Work Plan, the parameters of interest for all the monitoring locations are as follows:

Alkalinity	Potassium	pH
Arsenic	Magnesium	Sulfide
Cadmium	Manganese	Sulfate
Chloride	Sodium	TDS
COD	Nitrate	DOC
Conductivity	Lead	TSS
Iron	Phenolics	Zinc

Additionally, carbon disulfide was analyzed for each sample. Several of the collected samples during both the first and second round of sampling were analyzed for the full CLP list of organic parameters.

Sampling of the monitoring wells and piezometers at the Avtex facility was conducted by G&M personnel in accordance with the approved Avtex workplans. Sampling typically included evacuating a minimum volume of water from each well to remove stagnant water, followed by the collection of the sample. Because of the potential of encountering carbon disulfide (CS_2) and hydrogen sulfide (H_2S) vapors during well evaluation and sampling procedures, continuous air monitoring was conducted in the work area. Additionally, the air space directly above each well head was monitored for H_2S before any evacuation or sampling was performed. Level C personal protection was implemented during all sampling activities. All well sampling was accomplished by three, two-man, G&M crews. Two crews were responsible for evacuating the wells, while the third conducted the sampling.

Well evacuation consisted of measuring the static water level using a Well Wizard TM water level meter and removing a minimum of three well volumes of water from each well. This was accomplished through the use of either a Grundfos stainless steel submersible pump or for shallow wells within suction lift, a centrifugal pump. A hand-operated guzzler pump was used for the 2-inch-diameter viscose basin wells. In all cases, 3/4-inch-diameter flexible, ABS tubing was used during evacuation activities. Previous sampling of Well GM-8 indicated the ground water within the well to be of a corrosive nature and therefore, incompatible with submersible pumps. Consequently, air-lift methods were used to evacuate Well GM-8. In addition, the depth to water in this well was sufficiently deep to preclude the use of centrifugal pumps. Because of the relative remoteness of Well MW-1, a teflon bailer was used to evacuate the required well volumes. Water evacuated from each well was drummed and transported to the wastewater treatment plant.

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Evacuation procedures differed for wells which were pumped dry before the three required well volumes were removed. These wells, generally located near the viscose basins, were allowed to recover for approximately 30 minutes, and evacuated a second time. This procedure was repeated until either three well volumes had been removed or the well had been dried three times.

To ensure that all standing water within the well was removed, evacuation commenced by slowly lowering the pump or water line from the static water level to the desired pumping depth. This procedure was repeated several times during evacuation activities.

Following evacuation, each well was sampled using a teflon bailer. An additional five to ten gallons of water was bailed from each well before sample collection commenced to ensure that chemical equilibrium was achieved between the bailer and water. Sample containers were provided by the laboratory performing the approved work plan analyses. Containers for analyses requiring preservative were prepared by the laboratory in accordance with EPA accepted protocols. Non-preserved containers were rinsed prior to sample collection with a small amount of the sample water, while containers with preservative were not. Water samples undergoing metal analyses were filtered in the field prior to being introduced into their preserved containers. Upon collection, all samples were stored in their appropriate containers on ice and shipped to the laboratory using the approved custody protocols as described in the Sampling and Analysis section of the Work Plan.

Equipment decontamination procedures were employed during all evacuation and sampling activities to minimize the potential of cross-contaminating wells or sample containers.

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All reuseable evacuation and sampling equipment was decontaminated by washing it in a strong laboratory soap solution (MICRO) followed by tap water and distilled water rinses. Submersible pumps were washed in sealed six-inch-diameter PVC tubes. The soap solution was circulated continuously through the pump for several minutes. Following the soap wash, the pump was transferred to a PVC tube used only as a rinse tube. First, tap water, then distilled water, was circulated through the pump. Teflon bailers were decontaminated by first disassembling them, followed by a soap wash in a sealed, two-inch-diameter, PVC tube. Each bailer was then rinsed with several tap water and distilled water rinses. Separate tubes were used for wash and rinse operations.

Multiple teflon bailers were used during the sampling exercise and tagged for use at specific sampling locations. Several bailers were used exclusively for those wells containing degraded fluids; while, an additional set of bailers were used at clean locations. This procedure greatly reduced the risk of cross-contamination.

All bailer rope and ABS tubing from each well evacuation and sampling was not reused.

During all evacuation and sampling activities, G&M personnel wore SANAREXTM suits, PVC inner and nitrile outer gloves, rubber boots, helmets, and full-face, air-purifying respirators.

2.3 Drilling Program

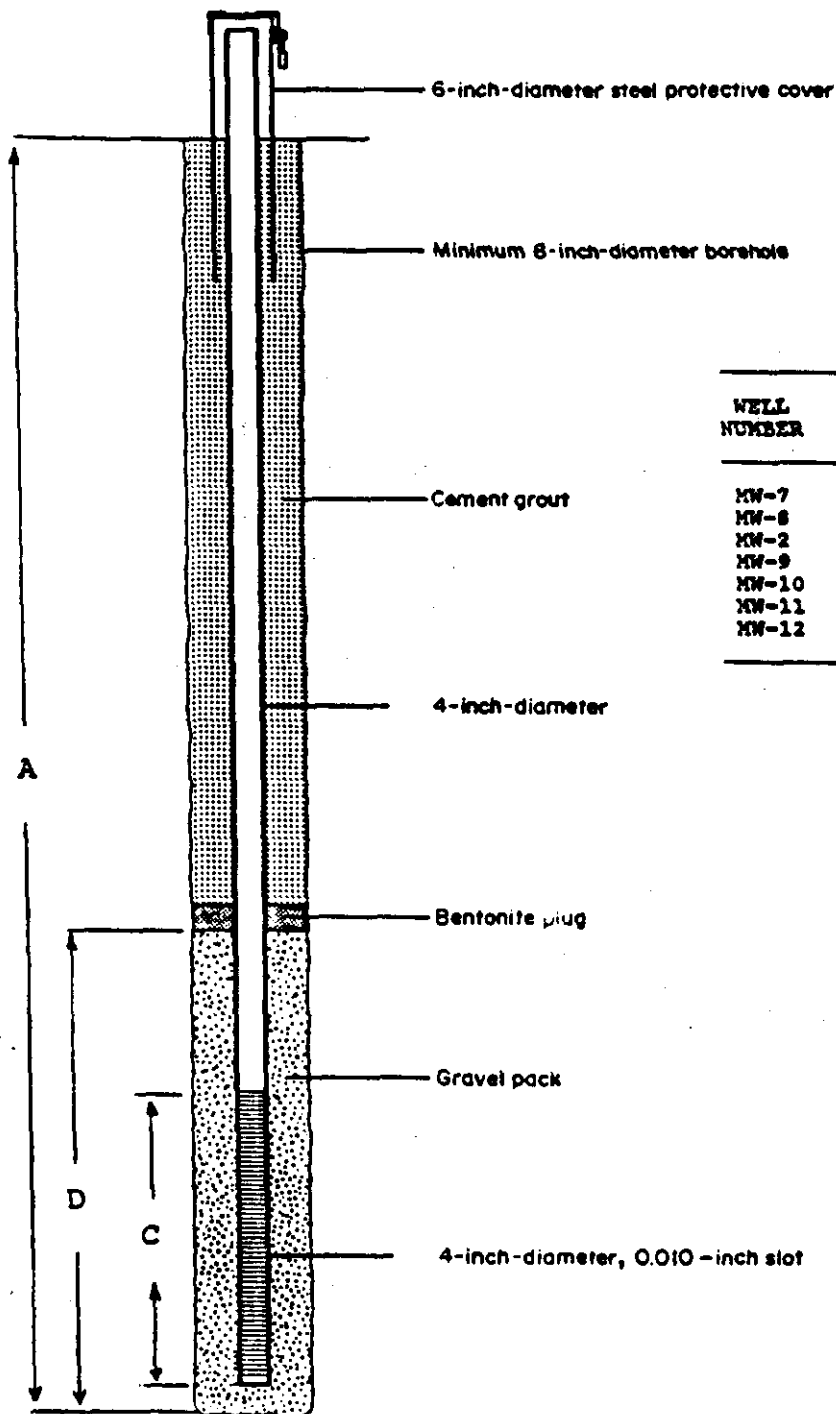
The Pennsylvania Drilling Company, of Pittsburgh, Pennsylvania, under the direction of G&M, conducted a three-phase drilling program at the Avtex facility during June, July, and August 1987. The purpose of the program was to

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provide additional monitoring points at the facility to further characterize the site hydrogeology, to determine shallow ground-water quality, and to collect waste samples for chemical and geotechnical testing.

The first phase of the drilling program provided for the installation of eleven shallow bedrock wells along the eastern bank of the South Fork of the Shenandoah River. The second phase provided for the installation of four wells in the unconsolidated deposits hydraulically downgradient of the viscose basins. Piezometers, installed within the viscose basins for the collection of liquid and solid waste samples and for making head determinations, constituted the third phase of this program. The locations of the wells and piezometers constructed as part of this program, as well as those constructed previously, are represented as Figure 1.2 in Section 1.0 and Appendix A. In addition, a summary of well-construction details and survey data are presented as Figures 2.1 through 2.4.

During all phases of the drilling program, G&M personnel took steps to protect on-site personnel from exposure to CS₂ vapors. Continuous air monitoring for the presence of H₂S and CS₂ was performed by a G&M technician during all drilling and sampling operations to determine appropriate levels of personal protection. A portable, battery-operated, dual alarm, hand-held scientific industrial Model HS265 Hydrogen Sulfide Monitor was used to determine the presence of H₂S. The HS265 Hydrogen Sulfide Monitor was capable of providing continuous air monitoring for H₂S levels from 0 to 1999 ppm. A digital liquid crystal display provided a constant readout of H₂S concentrations in 1 ppm increments. An audible alarm warned field personnel when H₂S concentrations reached the preset Threshold Limit Value (TLV) of 10 ppm. In addition, the Avtex facility provided field personnel with COMPAR 4100

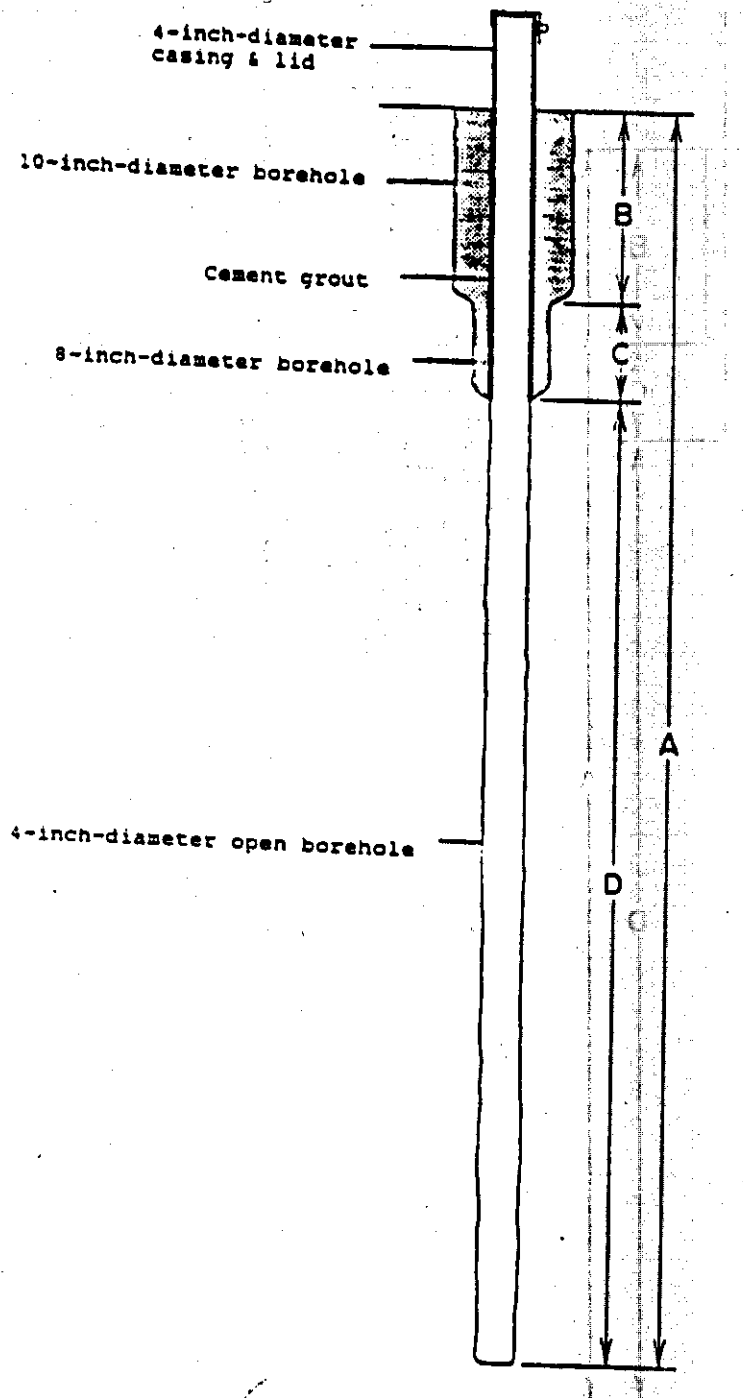


WELL NUMBER	FEET				CASING ELEVATION
	A	B	C	D	
MW-7	40	21	5	17	533.21
MW-8	40	20	5	18	530.00
MW-2	28.5	28.5	5	18.5	526.57
MW-9	42	--	15	20	524.76
MW-10	53.5	--	15	25.5	527.70
MW-11	30	30	10	17	525.98
MW-12	13	13	5	8.5	507.13

Figure 2.1 Well Construction Details for Surface Wells

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Stainless Steel Construction

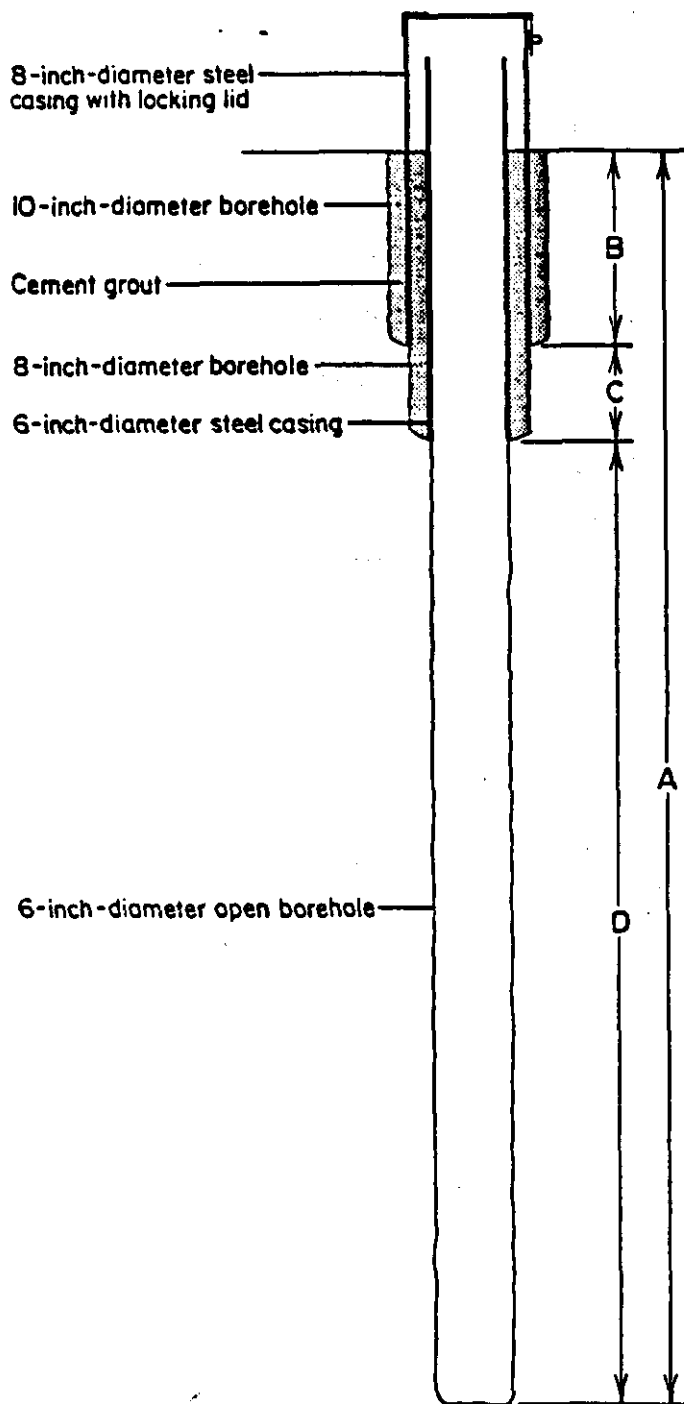
WELL NUMBER	FEET				CASING ELEVATION
	A	B	C	D	
PZ-1	15	11	7	17	478.15
PZ-2	16	9	4.5	1.5	477.56
PZ-3	18	7	6	5	475.01
PZ-4	31.5	10.5	6.5	14.5	479.91
PZ-5	25.5	7.5	5.5	12.5	477.04
PZ-6	23	8	4	11	478.81
PZ-7	23	10	3	10	479.75
PZ-8	18	8	5	5	479.37
PZ-9	28	8	15	5	478.81
PZ-10	18.5	9	4	5.5	480.17
PZ-11	80.25	8	42	30.25	479.54

Mild Steel Construction

WELL NUMBER	FEET				CASING ELEVATION
	A	B	C	D	
MW-1	35	26.5	0	8.5	552.73
MW-3	45	30	2.5	12.5	526.20
MW-4	40	31	2.5	6.5	498.59
MW-5	33	22	0	11	492.60
MW-6	40	33.5	0	6.5	502.59

Figure 2.2 Well Construction Details for Four-Inch Bedrock Wells

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WELL NUMBER	FEET				CASING ELEVATION
	A	B	C	D	
PW-0	158	23	10	125	506.03
PW-1	162	17	13	112	505.90
PW-2	150	31	12	107	498.32
PW-3	157	31	9	117	498.68
PW-4	156	31	12	115	496.28

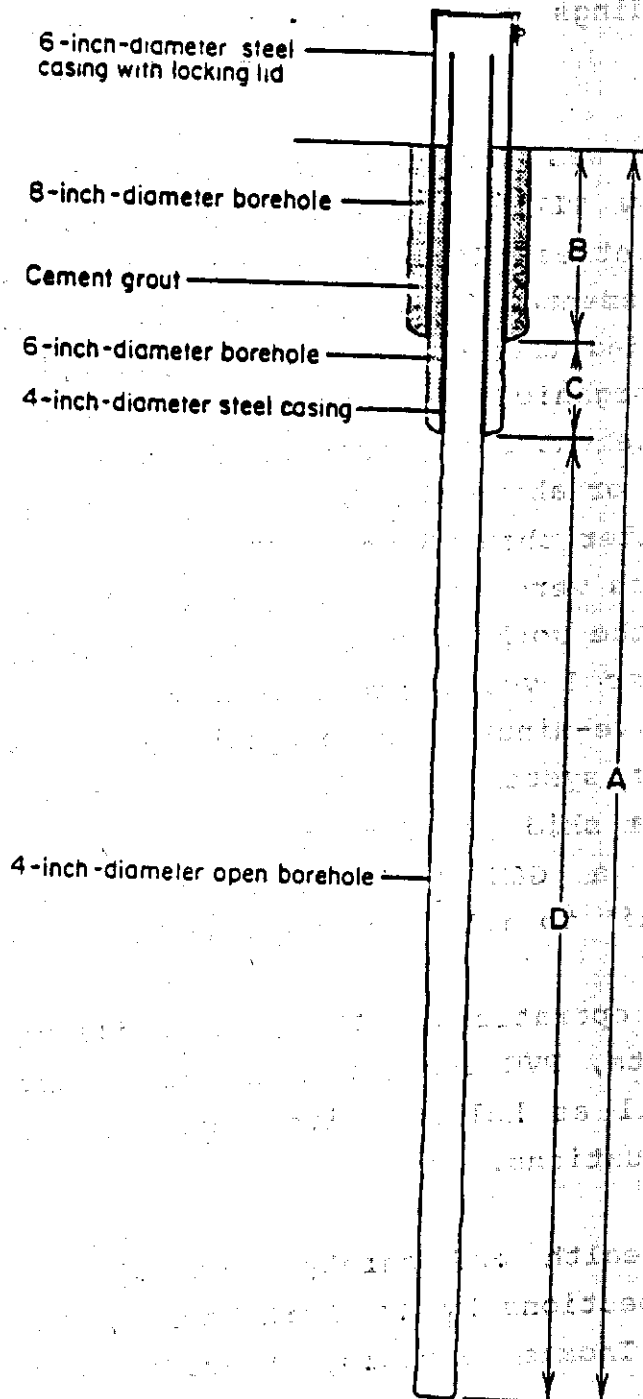
WELL NUMBER	FEET				CASING ELEVATION
	A	B	C	D	
91 Ritter	275	-	-	-	611.80
136 Nagi	205	-	-	-	494.78
137 Smith	65	-	-	-	489.89
141 Longerbeam	94	-	-	-	492.04
162 Frum	62	-	-	-	489.90
177 Young	65	-	-	-	499.70
178 Brown	120	-	-	-	511.80
179 Weatherholts	110	-	-	-	511.90
181 Schilling	174	-	-	-	511.20
185 Martin	72	-	-	-	492.85

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Figure 2.3 Well Construction Details for PW series Wells
 and Rivermont Acres Domestic Wells

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Geraghty & Miller, Inc.



WELL NUMBER	FEET				CASING ELEVATION
	A	B	C	D	
GM-1A	100	37	7	62	500.39
GM-1B	150	30	70	50	497.72
GM-2A	100	20	8	72	489.80
GM-2B	175	20	30	75	490.40
GM-3	125	19	3	103	485.26
GM-4	122	16	5	101	490.73
GM-5	125	32	10	83	498.99
GM-6	152	33	10	109	497.90
GM-7	125	17	10	98	486.08
GM-8	132	40	10	82	525.55
GM-9	152	40	10	102	505.99

Figure 2.4 Well Construction Details for GM Series Wells

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Monitox Personal Alarms for use as backup H₂S air monitors. A National Draeger, Inc., Gas and Vapor Detector, in conjunction with specific gas-sensitive calorimetric tubes (Draeger tubes), were utilized to detect the presence of CS₂. Positive H₂S monitor readings were also verified using Draeger tubes.

In the event that H₂S was detected at concentrations between 5 and 8 ppm (below TLV) or CS₂ was found to be present at concentrations between 10 and 95 ppm, Level C personal protection was implemented for all personnel. Level C personal protection included the use of MSA air-purifying full-face respirators with organic vapor canisters. Level B personal protection was implemented if concentrations of H₂S were consistently present at or above the TLV (10 ppm), or if CS₂ concentrations were greater than 95 ppm. Whenever Level B personal protective measures were implemented, drilling was halted and all personnel in the work area donned supplied-air respirators. Personnel under Level B protection were also equipped with the ISI-ARAP five-minute escape cylinder in the event that the supplied-air system failed. A six-bottle cascade system, mounted to a skid platform or trailer, was continuously monitored by a G&M technician to ensure continuous flow of supplied air to all level personnel.

During all drilling operations, G&M and drilling personnel wore SARANEXTM suits, PVC inner and nitrile outer gloves, rubber boots, as well as helmets with face shields during all wet or contact situations.

Compliance with site health and safety protocol was ensured through periodic inspections by Mr. Mark Wagner, G&M project manager, and Mr. Thomas Sturgis, President of Pennsylvania Drilling Company.

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2.3.1 Riverbank Well Installation

Eleven shallow bedrock wells (designated PZ series) were constructed along the eastern bank of the South Fork of the Shenandoah River during June and July, 1987. These wells serve as monitoring points for the quality of the shallow ground water and to determine the dynamics of hydrology at the interface of the subsurface and surface-water systems. These wells are open borehole wells (i.e., not screened) and range in depth from 16 to over 80 feet. The open-hole midpoint for these wells range from 14.3 feet to 66.1 feet below land surface.

Well construction was accomplished in several steps. Initially, oversize hollow stem augers were utilized to advance the borehole to bedrock. This provided a conduit through the overburden through which a 8-inch diameter, low carbon steel casing was lowered to the bedrock surface. Depth to bedrock ranged from 7 to 11 feet below land surface. This temporary casing was sealed into the bedrock by pushing it approximately six inches into the rock using a compressor-driven 7-5/8-inch air hammer bit. To provide a secure anchoring point for a permanent stainless steel casing, the borehole was then advanced 2 to 10 feet into bedrock by drilling inside the carbon steel casing using the air hammer bit. Hammer oil was applied sparingly to the bit to provide adequate lubrication.

Four-inch diameter, flush-joint stainless steel casing was then lowered into the borehole and pressure grouted in place with a bentonite/cement slurry consisting of five percent bentonite and Type V sulfate-resistant cement. The grout was injected, via tremmie pipe, outside the stainless steel casing until it emerged at ground level. The stainless steel casing was then lifted slightly by the drill rig to

allow grout to enter the inside of the casing, thereby ensuring an adequate seal was formed between the casing and the rock surface. The temporary casing was then removed from the borehole and additional grout tremmied into the borehole until it emerged at ground level. The grout was allowed to cure overnight before additional drilling was performed.

The following day, the borehole was advanced to its final depth by drilling inside the stainless steel casing using a 3-3/4-inch diameter roller cone bit and air rotary drilling techniques. Final depth was based upon the intersection of fractures yielding sufficient ground water for development and sampling. Geologic logs and well construction details for each well installation are presented as Appendices E and F, respectively.

Two well clusters were installed to determine the hydraulic head for distinct saturated bedrock zones. One cluster, comprised of PZ-1 and PZ-2, is located at the northwest corner of Sulfate Basin 1. The second cluster includes PZ-8, -9, and -11 and is located near the dividing line between Sulfate Basins 2 and 4.

Soil and rock samples were collected from cuttings at five-foot intervals during construction of each riverbank well. The samples were collected in clear plastic zip-lock bags or glass jars and labeled with the site location code, boring identification number, sampling date, sample depth, and any other pertinent information. Each sample was retained by the G&M field geologist for subsequent lithologic description.

Equipment decontamination procedures were employed during these drilling operations to minimize the potential of introducing contaminants from one well to the next during

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well-construction activities. Before being relocated to a different drilling site, all equipment used during drilling and well construction was moved to the top of the adjacent berm and washed with potable water. Wash and rinse water was directed into adjacent sulfate basins. Decontamination procedures differed slightly for wells PZ-9 and -11. These wells penetrated zones of increased ground-water degradation; and, therefore, equipment decontamination was performed at the Avtex water treatment facility, and all fluids were directed into the treatment system.

Drilling of the riverbank wells proceeded slowly due to heat stress and restricted mobility imposed by personal protective equipment. Air temperatures greater than 90 degrees were common throughout this phase of the drilling program. In addition to limiting the speed at which drilling could proceed, the heat may have affected H₂S air monitoring equipment. While drilling PZ-7, H₂S concentrations of approximately 35 ppm were detected by the H₂S meter at the auger hole. Subsequent verification using Draeger tubes indicated no H₂S or CS₂ was present; however, the meter continued to indicate elevated levels of H₂S. All site personnel remained in Level C protection, and backup H₂S meters were obtained from the Avtex facility.

Problems associated with Well PZ-10 also resulted in work slowdowns. During well development, air bubbles were observed along the outside of the stainless steel casing. The G&M field geologist decided to proceed with the drilling program and determine the integrity of the well installation at a later date. Subsequently, a replacement well was installed in the vicinity of PZ-10. While drilling the replacement well, air bubbles were observed rising from the river bottom along the shoreline opposite the drilling rig.

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Drilling was halted at 20 feet and well development using the drilling tools commenced.

Air bubbles observed outside the casing of PZ-10 during well development indicate an inadequate seal was formed between the well casing and borehole wall. Air bubbles observed rising from the riverbed while drilling the replacement PZ-10 indicate the presence of a fracture zone capable of fluid/air transmission. The extent of this zone was not determined, however, because bubbles were only observed along the shoreline opposite the rig, indicating this may be a localized fracture zone.

The original PZ-10 was abandoned by grouting the borehole to ground surface using a slurry consisting of five percent bentonite and Type V cement. The well casing could not be removed and, therefore, was cut at ground surface.

Access to the riverbank wells was limited due to the presence of relatively high, steep berms which serve as retaining walls for the sulfate basins. The wells were sited along a narrow strip of wooded land between the base of the berms and the edge of the river. A Case 450 bulldozer was required to construct roads to each well site and to clear work areas. Because of the steepness of the berms, it was also used to lower, and subsequently retrieve, the drill rig and associated equipment to and from each well site.

Well development was performed by air lifting water, silt, drill cuttings, and other material which may have settled in the borehole at the conclusion of drilling. Each well was blown dry three to five times using a Sound Design D-450 air compressor. Field parameters (i.e., pH, specific conductivity, and temperature) were determined by G&M personnel as part of well-development procedures.

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2.3.2 Viscose Basin Perimeter Wells

Phase 2 of the drilling program consisted of the construction of four screened wells (MW-9, -10, -11, and -12) within the unconsolidated deposits hydraulically downgradient of Viscose Basins 1, 7, 9, and 10 during July and August, 1987. These wells serve as monitoring points to determine shallow ground-water quality downgradient of these basins and range in depth from 13 to 53.5 feet.

The viscose basin perimeter wells were constructed using hollow-stem auger techniques. Each borehole was advanced to the desired depth using 10-inch diameter hollow-stem augers. With the exception of MW-10, total depth of the wells was determined by the depth to bedrock.

Soil samples were collected during auger advancement at 2.5-foot intervals using a split-spoon sampler. Samples were collected in clear glass jars and labeled as described in Section 2.3.1 and retained by the G&M field geologist for subsequent lithologic description. After sample collection, the split-spoon sampler was washed with a strong laboratory soap solution (MICRO), rinsed with tap water followed by distilled water, and allowed to air dry.

Well construction consisted of lowering four-inch diameter stainless steel casing and 10-slot wire-wound stainless steel screen into the borehole through the auger annulus. While the augers were being removed, a coarse-grain gravel pack was installed to approximately three to five feet above the top of the screen. A bentonite pellet seal, two to three feet thick, was constructed above the gravel pack. In the event that the gravel pack was constructed above the water table (MW-10, -11, and -12), one to two gallons of dis-

tilled water was poured down the borehole onto the bentonite pellets to induce swelling and sealing, thereby preventing grout from migrating into the gravel pack. The stainless steel casing was then grouted in place with a bentonite/cement slurry consisting of five percent bentonite and Type V cement. The grout was pressure injected, via tremmie pipe, from the top of the bentonite seal to the ground surface. Geologic logs and well construction details for each basin-perimeter well are presented as Exhibits E and F, respectively.

Continuous air monitoring, as described in Section 2.3, was conducted during the drilling of the basin perimeter wells. Level B protection was implemented for all personnel during basin perimeter-well drilling activities because of elevated H_2S and CS_2 concentrations within the work space. The level of protection was downgraded during well emplacement activities when concentrations of H_2S and CS_2 met site health and safety criteria.

Various work slowdowns occurred during well construction due to excessive heat, mobility restrictions imposed by personal protection equipment, slow auger penetration, auger refusal, and a slightly underpowered drill rig. Additional slowdowns were experienced while setting Well MW-9. After setting the gravel pack to 30 feet, and while removing the augers from the borehole, saturated dike materials ran up inside the augers to a depth of 18 feet. In an attempt to force the gravel pack toward the well screen, the G&M field geologist pulled the augers to 25 feet and added gravel while pumping the mud from inside the well. This procedure appeared to be working until the augers bridged at 16 feet. Efforts to free the augers resulted in breaking the well casing. The augers, with the casing and screen stuck inside, were removed from the borehole the following day.

A second attempt at setting Well MW-9 was made on July 15. The oversized augers were reinserted into the borehole to 25 feet. After removing material which had run up into the augers, a new screen and casing was set in the borehole. However, viscous mud flooded the casing at 35 feet and efforts to flush the mud from the borehole were unsuccessful. The well screen and casing was, therefore, removed from the well the following day. The oversized augers were left in place and drilling of Well MW-10 was started using the 8-inch diameter augers.

On the morning of July 22, Well MW-9 was successfully set. However, the gravel pack bridged at 34 feet, making it necessary to flush it down the borehole with water. Level B protection was implemented during all attempts to set the well because of elevated CS_2 concentrations in the work area.

Problems were also experienced with Well MW-12. Because it would not produce an adequate volume of water for time-efficient well development and sampling, a second well was installed approximately 50 feet north of the original well. This replacement well produced sufficient water for development and sampling. The original well was, therefore, abandoned by filling it with a mixture of grout (bentonite/Type V cement) and backfill material. The well casing was cut at the ground surface after all attempts at removing it failed.

2.3.3 Viscose Basin Boring Program

Phase 3 of the drilling program, the Viscose Basin Boring Program, was initiated during August, 1987. The purpose of this program was to obtain information on the physical and chemical characteristics of five closed basins

(Viscose Basins 1, 2, 3, 7, and 8) and three open basins (Viscose Basins 9, 10, and 11) and consisted of the construction of six piezometers, bedrock coring in the closed basins, basin sampling of solid and liquid wastes, and two in-situ Vane shear tests. Of the eight basins, seven were successfully drilled to clay or bedrock, while one (Viscose Basin 8) was found to be impenetratable because of concrete fill material.

The Viscose Basin Boring Program was conducted in two steps; the Closed Basin Investigation followed by the Open Basin Investigation. The primary differences between each investigation included drilling methodologies and well-installation techniques. Hollow-stem augering and NX coring were employed during the Closed Basin Investigation, while a driven-casing drilling technique was utilized during the Open Basin Investigation for well installation. Common to each investigation was the collection of basin waste materials using split-spoon samplers and Shelby tubes. Selected samples were packaged for shipment to the three laboratories involved in chemical and geotechnical analyses.

Laboratories involved include:

Cambridge Analytical Associates, Inc.- Solid and liquid chemistry

Spotts, Stevens & McCoy, Inc. - Solid chemistry

Froehling & Robertson, Inc. - Geotechnical testing

2.3.3.1 Closed Basin Investigation

The Closed Basin Investigation included the installation of piezometers and collection of waste samples within Viscose Basins 1, 2, 3, and 7, as well as NX coring of the bedrock underlying these basins.

Piezometer construction within the closed basins was accomplished at the conclusion of bedrock coring using a Simco track drill rig and hollow-stem auger techniques. Each borehole was advanced to bedrock using six-inch-diameter hollow-stem augers. During augering, split-spoon samples and Shelby tubes were collected, ahead of the lead auger flight, to identify the encountered material.

When contact with bedrock was made, drilling was continued from within the hollow-stem augers into the bedrock by NX coring to collect intact rock samples to identify lithology and important structural features within the rock matrix. Rock cores, 10 feet long, were collected in 12-foot long NX core barrels from each of the four basins. Each core was stored in a wood core box and retained by G&M for review and lithologic description. The core logs are presented as Appendix E.

2.1.3.2 Open Basin Investigation

The Open Basin Investigation included the installation of piezometers and collection of waste materials from Viscose Basins 9, 10, and 11. Drilling within the basins was accomplished using a platform-mounted skid rig. A plywood walkway was constructed from the berm to the drilling rig for access. A crane lowered the rig and all equipment and materials required during drilling and sampling onto each basin. Personnel were, likewise, lowered to the basin surface. The crane operator remained on site at all times during drilling and sampling activities in the event an emergency required personnel or equipment to be removed from the basin. No such emergency was encountered.

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Basin drilling and sampling commenced by sampling the upper four to five feet of waste material using split-spoon samplers and Shelby tubes. After sampling the upper zone of the basins, the Skid rig and a 318-lb hammer drove a four-inch diameter steel casing into the waste material within the basin. Split-spoon and Shelby-tube samples were collected ahead of the driven casing until natural earth materials were encountered. Piezometers were then constructed in Viscose Basins 9 and 11 by setting a two-inch diameter stainless steel well screen and casing at or near the bottom of each sampled borehole. A clean, silica-sand gravel pack was installed to a depth just below the four-inch diameter steel casing. The casing was then removed to prevent bridging and the gravel pack was raised above the well screen. A bentonite pellet seal was installed above the gravel pack; and, the stainless steel well casing was grouted in place with a thick bentonite slurry.

At Viscose Basin 10, the drilling pipe was driven to 20 feet and could not be retrieved from the borehole. It was, therefore, grouted in place. No piezometer was installed in this basin.

A summary of materials encountered during the drilling in both the closed and open basins is presented as Table 2.1. Waste material description for each basin and piezometer construction details are presented as Appendix G.

TABLE 2.1 SUMMARY OF ENCOUNTERED MATERIALS
 IN AVTEX VISCOSE BASINS

Material Type (General)	Closed Basin No. (intervals in feet, from surface)				
	1	2	3	7	8*
Fill or Cap (predominantly clay)	0-1.0	0-2.0	0-2.5	0-14.0	>5.0
Black Fibrous and/or Rubberlike Materials	1.0-9.0	2.0- 9.0	2.5-5.0	14.0-23.0	N/A
Natural Deposits (predominantly clay)	9.0-29.0	9.0-25.0	5.0-29.0	23.0-30.0	N/A
Bedrock	29.0+	25.0+	29.0+	30.0+	N/A

Material Type (General)	Open Basin No. (intervals in feet, from surface)		
	9	10	11
Cellulose Crust Material	0-0.5	0-0.5	0-0.5
Moist, White, Soft Material	0.5-2.0	0.5-2.0	0.5-2.0
Rubberlike Material	2.0-23.0	2.0-23.0	2.0-16.5
Natural Deposits (predominantly clay)	23.0-24.0+	23.0-24.0+	16.5+

*Viscose Basin 8 unpenetrable with auger rig - fill contains concrete slabs

**PHYSICAL CHARACTERISTICS OF
THE PROJECT AREA**

Section Three

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3.0 PHYSICAL CHARACTERISTICS OF THE PROJECT AREA

The following RI report section presents interpretations of the geology and ground-water environment based upon information collected during the RI field program. In addition, conditions in and around the viscose basins are discussed as they represent the primary contaminant source areas of concern with regard to the RI/FS. This approach is a result of discussions and ultimate approval by the Agency with regard to in-depth investigation of the conditions of the viscose basins and their interaction with the ground-water and surface-water environments. Within Section 3.0, the interaction of the basins with the ground-water and surface-water regimes are dealt with from a standpoint of basin material content location relative to the zone of saturated bedrock (i.e., bedrock aquifer), and the interpreted direction of ground-water flow in the horizontal and vertical dimensions. Information concerning the chemistry of the viscose basins and the ground-water system, and the interplay between the potential source areas and the ground-water are presented as Section 4.0.

It is important to point out that a number of hydrogeologic investigations have been performed by Avtex and its environmental consultant, G&M, over the past five years. Prior to the commencement of the CERCLA activities, G&M had developed information as to the geology at the facility and how the ground water within the bedrock system is controlled by the bedding-plane fractures, resulting in flow across the plant site from the northeast to the southwest. The RI-generated information further adds to this database by better defining the relationship of different zones of the bedrock aquifer with the surface-water regime, represented by the South Fork of the Shenandoah River.

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G&M had also presented information as to the extent of contamination and had concluded that the viscose basins located on a raised terrace above the floodplain at the Avtex facility probably represented the primary sources of contamination. It will be shown herein that, based on position of the water table relative to viscose basin contents, a higher degree of hydraulic connection between the waste material and the ground-water regime exists at the open viscose basins than at the closed basins. In addition, ground water within the confines of the project area has the Shenandoah River as its point of discharge.

3.1 Viscose Basins

During the course of the RI field program, several tasks were initiated to develop information concerning the physical nature of the viscose basins as to the location of the actual waste-material boundaries within the covered basins, and to assess the presence of mineralized fluids emanating laterally away from the basins. In this effort, G&M performed surface geophysics, the installation of wells within unconsolidated deposits hydraulically downgradient of the viscose basins, and installation of piezometers within the basins to determine fluid levels within the waste material compared to ground-water levels. The mechanisms of each of the activities have been discussed in Section 2.0 and conclusions concerning the work in and around the viscose basins are presented herein.

3.1.1 Electromagnetic Survey

The primary objective of the electromagnetic (EM) terrain conductivity surveys performed at the Avtex site was to delineate the boundaries of several of the decommissioned viscose basins, specifically basin numbers 1, 2, 3, 7, and 8.

A secondary objective of the EM surveys was to determine if shallow plumes of highly conductive fluids may be emanating from the other basins at the site.

The EM terrain conductivity method consists of a power source and transmitting and receiving coils. Current flowing in the transmitter coil generates an electromagnetic field which induces eddy currents into the ground, and within each eddy current, in turn, produces a secondary electromagnetic field which is proportional to the magnitude of the current flowing in that loop. A part of the magnetic field from each loop is intercepted by the receiver coil, resulting in an output voltage which is related to the conductivity of the subsurface materials. The conductivity measurement that is obtained is the average longitudinal conductance of all the material from ground surface to the effective depth of penetration of the device. This is commonly referred to as the bulk electrical conductivity.

The depth of investigation of the EM method is a function of the coil separation, the coil orientation, and the signal frequency. The EM surveys at the Avtex site were run using a Geonics EM-31. The EM-31 operates at a fixed frequency and coil separation, but is capable of collecting apparent conductivity data from two different probing depths, depending upon the orientation of the coils. If the instrument is oriented such that both the transmitter and receiver coils are aligned in the same vertical plane (i.e., vertical coplanar), the depth of investigation is approximately three meters. When both coils are aligned in the same horizontal plane (i.e., horizontal coplanar), the probing depth is increased to about six meters.

Provided as Figures 3.1 and 3.2 are maps indicating the general locations of anomalously high apparent conductivity identified by the EM-31 surveys. In the case of Basins 1 and 3, discrete apparent conductivity values were picked from the horizontal coplanar profiles at regular intervals. These data were then plotted on base maps and contoured to provide an alternate view of the data. The resulting contour maps are provided as Figures 3.3 and 3.4, respectively.

3.1.1.1 Viscose Basin No. 1

Due to relatively open terrain, good coverage was obtained in the vicinity of Viscose Basin 1, with a total of seven traverses being conducted over the area. Lines EM-11 through EM-16 were spread 50 feet apart and oriented generally north-south. Line EM-17 was used as an east-west tie line to the survey.

With regard to the positions of areas of anomalously high apparent conductivity, good agreement exists between the horizontal coplanar data and the vertical coplanar data. Although the vertical coplanar traverse yielded lower apparent conductivity values overall (see Appendix D), generally, lower readings observed in the vertical coplanar orientation are probably a function of the depth of investigation. Because the depth of investigation in the vertical coplanar orientation is only on the order of three meters, the relative amount of highly conductive material within the basin being included in the EM-31 reading is low. However, in the horizontal coplanar configuration, the EM-31 reading is being influenced by a greater volume of the contents of the basin, resulting in a higher apparent conductivity.

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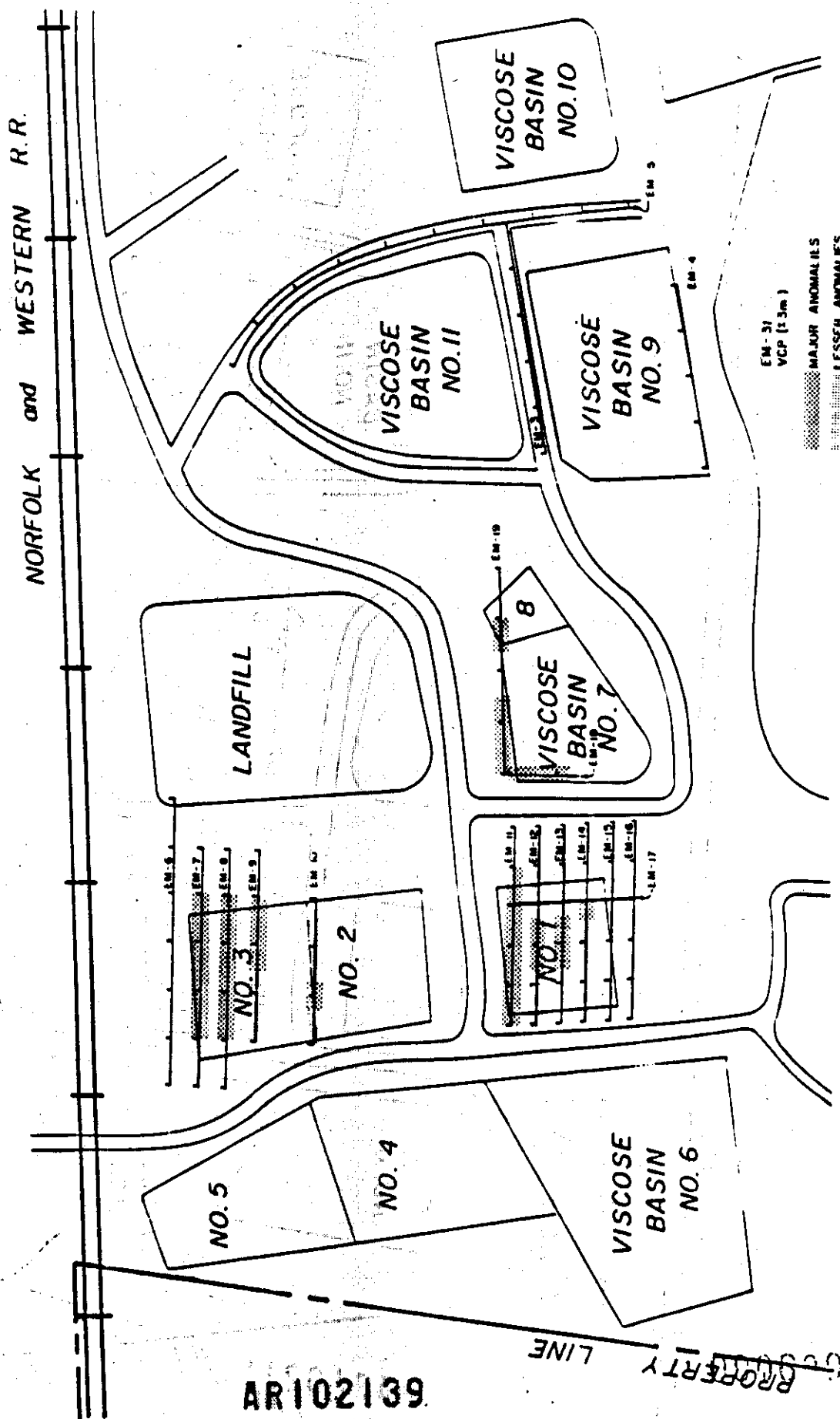


Figure 3.1 Locations of Apparent Conductivity Anomalies (VCP)

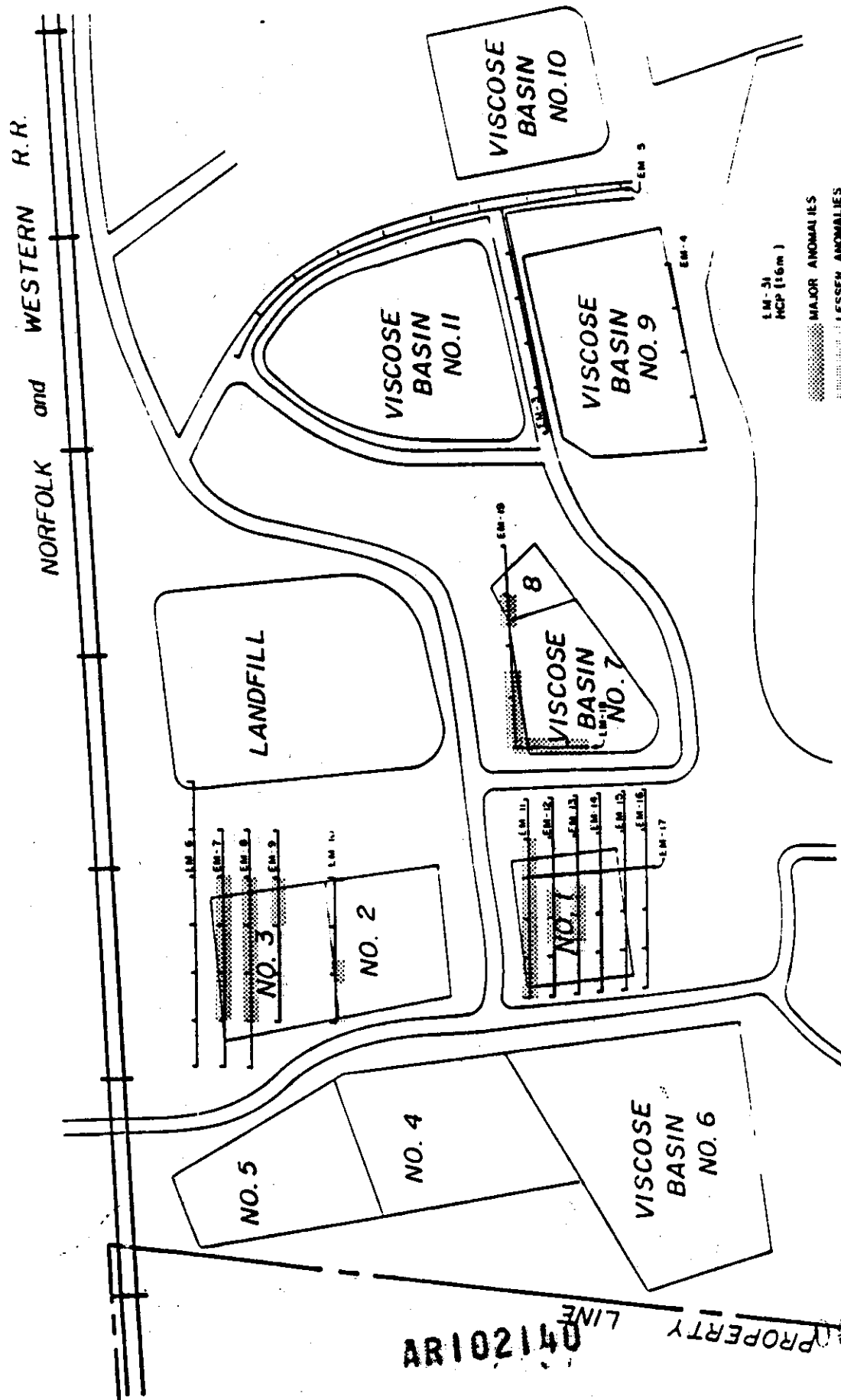


Figure 3.2 Locations of Apparent Conductivity Anomalies (HCP)

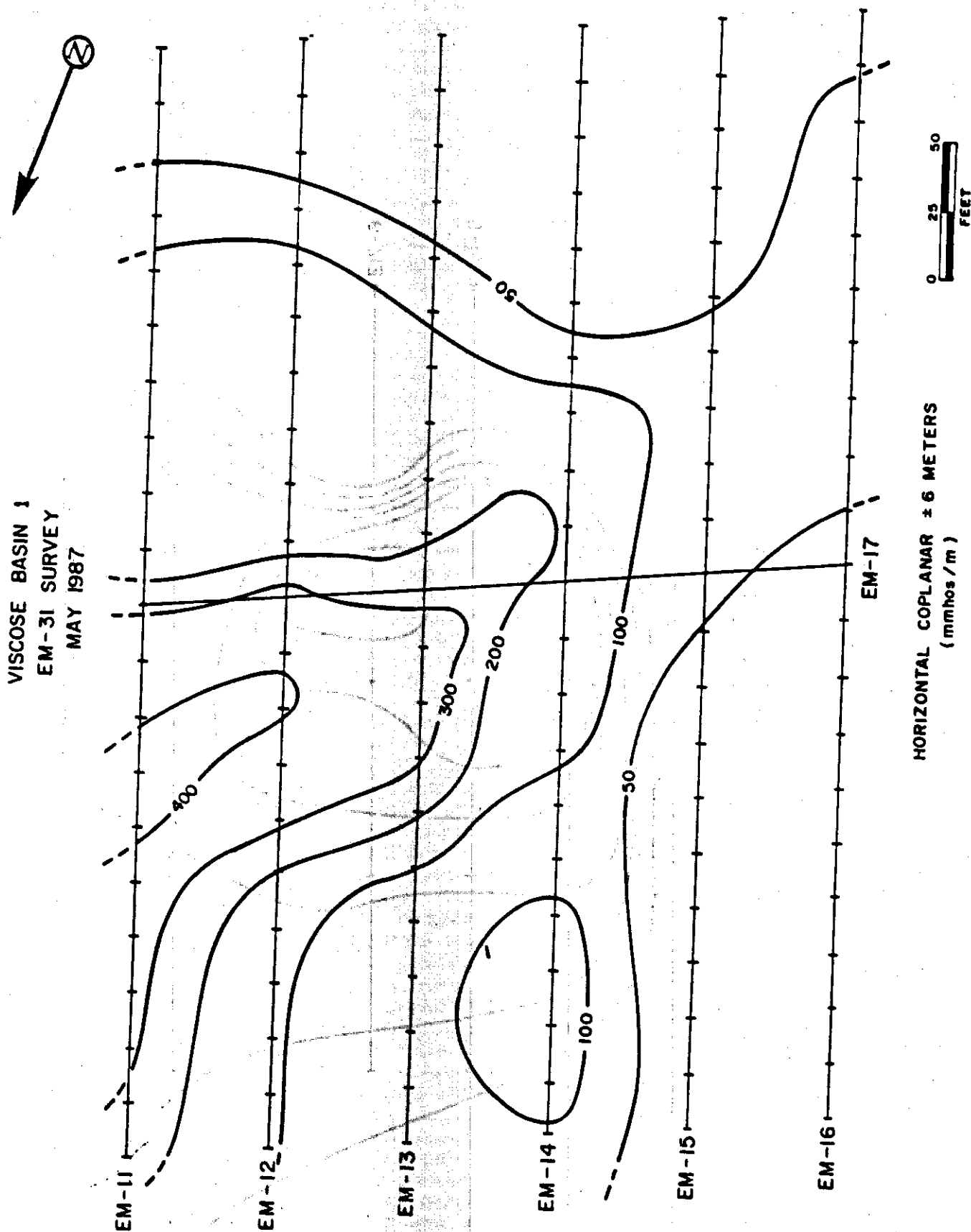


Figure 3.3 Apparent Conductivity Profile for Viscose Basin 1 (HCP)

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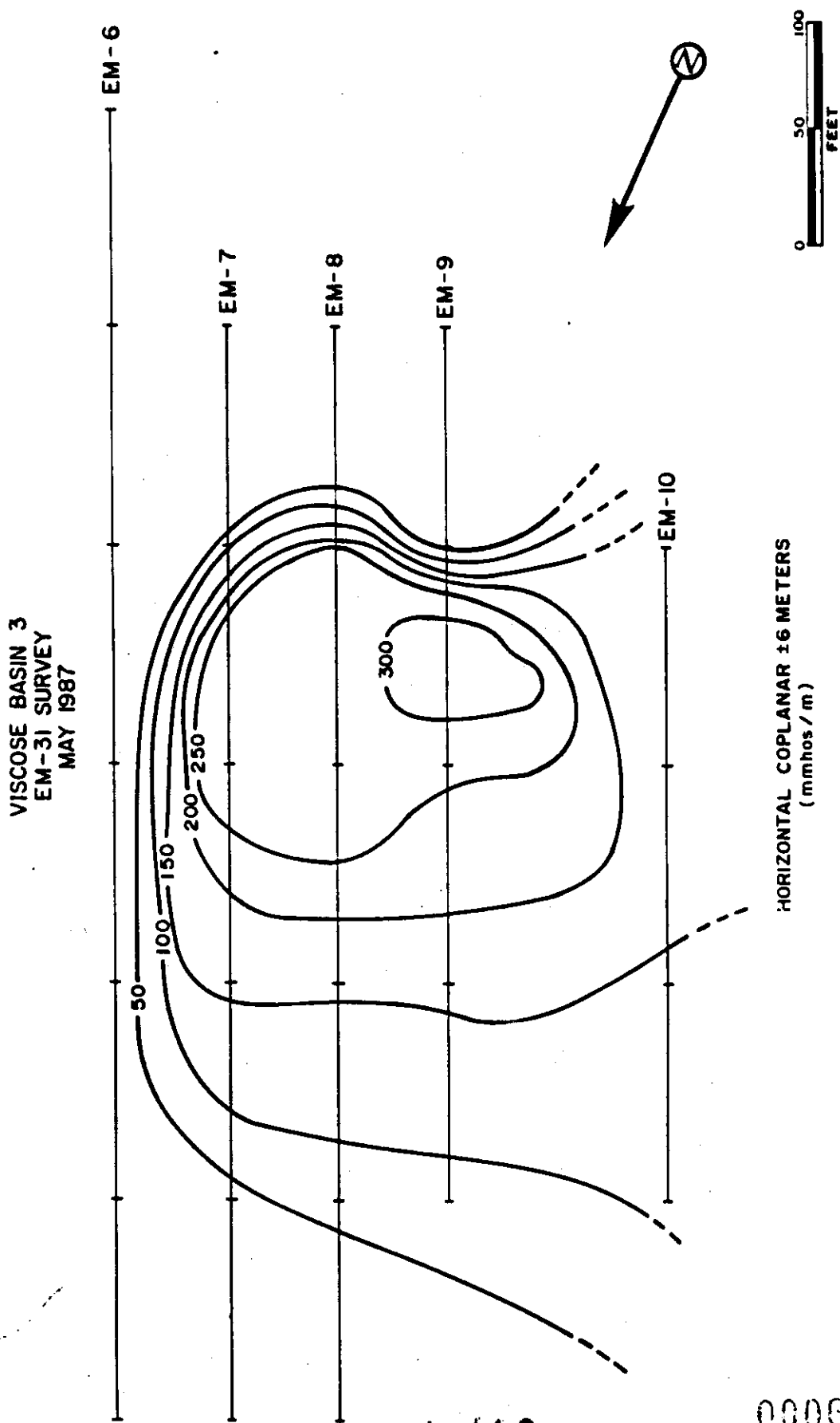


Figure 3.4 Apparent Conductivity Profile for Viscose Basin 3 (HCP)

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The EM-31 surveys conducted in the vicinity of Basin 1 also indicates a trend of increasing apparent conductivity near the center of the basin. This could be the result of increased saturation near the center of the basin and/or greater depth of waste materials in that area. In addition, the apparent conductivity data suggest that the north-south dimension of Basin 1 may be somewhat larger than is suggested by Avtex basin maps.

Finally, the EM-contour map shown as Figure 3.3 indicates a zone of increased apparent conductivity extending toward the southwest from the southwestern corner of the basin. These data may reflect the presence of residues from past or intermittent migration of mineralized fluids away from the basin (e.g., during the time that the basin was active or following periods of high precipitation).

3.1.1.2 Viscose Basin Nos. 2 and 3

Access to Viscose Basins 2 and 3 was limited by dense underbrush and, in some areas, swamp-like conditions. As a result, EM-31 surveys could only be conducted over the eastern half of Basin 3 (lines EM-6 through EM-9) and also along an old roadway separating Basins 2 and 3 (line EM-10).

Apparent conductivity data collected over Basin 3 indicated that both the northern and southern boundaries of the basin may be situated slightly further to the south than what is presented on Avtex plant diagrams. Also, the individual profiles (Appendix D) show a general increase in the degree of saturation in that direction.

As was the case at Basin 1, apparent conductivity readings obtained in the horizontal coplanar configuration tended to be higher than those observed in the vertical coplanar dimension.

Data collected along survey line EM-10 suggest that the old dike separating Basins 2 and 3 may have become at least partially saturated with fluids from the basins, as evidenced by the relatively high apparent conductivity values observed along the traverse, especially in the northern half of the profile.

3.1.1.3 Viscose Basin Nos. 7 and 8

Due to the presence of a large mound of sodium sulfate, heavy vegetation, and very swampy conditions, EM surveys in the vicinity of Viscose Basins 7 and 8 were restricted to one traverse approximately along the eastern edge of the basins (EM-19) and another (EM-18) along a portion of the northern edge of the Basin 7.

The conductivity profile for lines EM-19 shows two distinct anomalies separated by a zone of low apparent conductivity. It appears that this low zone may represent a bermed area between the two former basins, while the broad anomaly at the north end of the profile is due to the saturated portion of Basin 7; the smaller peak toward the south end of the profile is caused by Basin 8. Given the limited coverage provided by these two survey lines, it is not possible to fully determine the lateral boundaries Viscose Basins 7 and 8. Based upon the anomalously high apparent conductivity values recorded along both of the traverses, it appears that the traverses are situated predominantly within the boundaries of the basins.

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3.1.1.4 Summary of EM Survey Findings

The electromagnetic terrain conductivity surveys were generally successful in delineating the extent of the No. 1 viscose basin. Apparent conductivity data from the traverses conducted over that area indicate that the north-south dimension of the basin may be somewhat greater than expressed on Avtex plant diagrams. In addition, the data suggest that the basin is deepest and/or most highly saturated near its center. Also, a zone of elevated apparent conductivity extending southwestward from the southwest corner of the basin suggest past or present movement of fluids from the basin in the shallow deposits in this area.

Due to limited accessibility, Viscose Basins 2 and 3 could not be thoroughly investigated using the EM-31. However, the results from survey lines EM-6 through EM-9 do indicate that Basin No. 3 may deepen and/or become more saturated in its southern half. Also, data from line EM-10 suggest that the dike separating Basins 2 and 3 may be saturated by basin fluids, especially along the northern half of the dike.

3.1.2 Hydraulic Head Relationships - Covered Viscose Basins

With the installation of piezometers within the viscose basins and screened wells in unconsolidated deposits proximal to the old viscose basins, G&M collected depth-to-fluid measurements from each installation. Values for depth to fluid were corrected to elevation based upon the Avtex datum. The Avtex datum represents mean sea level (MSL) minus 0.5 feet. For discussion purposes, all elevations given as MSL refer to the Avtex datum. Collected measurements for January 11, 1988 are depicted in cross section as Figures 3.5

and 3.6. In the vicinity of Viscose Basins 1 and 3, fluid levels within the basins are at or above the waste material and cover material interface. The fluid level within Viscose Basin 2 was determined to be below the waste material and cover material interface. Ground-water conditions downgradient of the three basins have been evaluated with data collected from Well MW-11. The depth to water in this well is approximately 25 feet lower than fluid levels present in the three closed basins (Figure 3.5). The same relationship is seen at Viscose Basin 7 (Figure 3.6). In this case, the waste material is located at a greater depth with a thicker layer of cover material. The observed fluid level from the piezometer installed within the basin is approximately 10 feet above the waste/cover material interface. In addition, the ground-water level as reflected by MW-12 is approximately 20 feet lower than the fluid level within Viscose Basin 7. The water level reflected by MW-12 is at or just below the approximate elevation of the bottom of the basin.

Although the MW series wells are located at some distance from the viscose basins, the difference in liquid elevations can be attributed to the permeability of the undisturbed soil horizons versus the viscose basin material. The basin cover material is a silty to clayey soil which will receive precipitation as recharge. The waste viscose material is characterized as a solid matrix with large void spaces capable of holding large volumes of percolating rainfall. The viscose basins will act much like a bathtub and fill with fluid from precipitation infiltration, since the cover material, which slopes towards the center of the basin, is of a higher permeability than the natural soil horizons encompassing the basins. As a result, the fluid within the basin will continue to build up hydraulic head during periods of heavy rainfall. The water level within the

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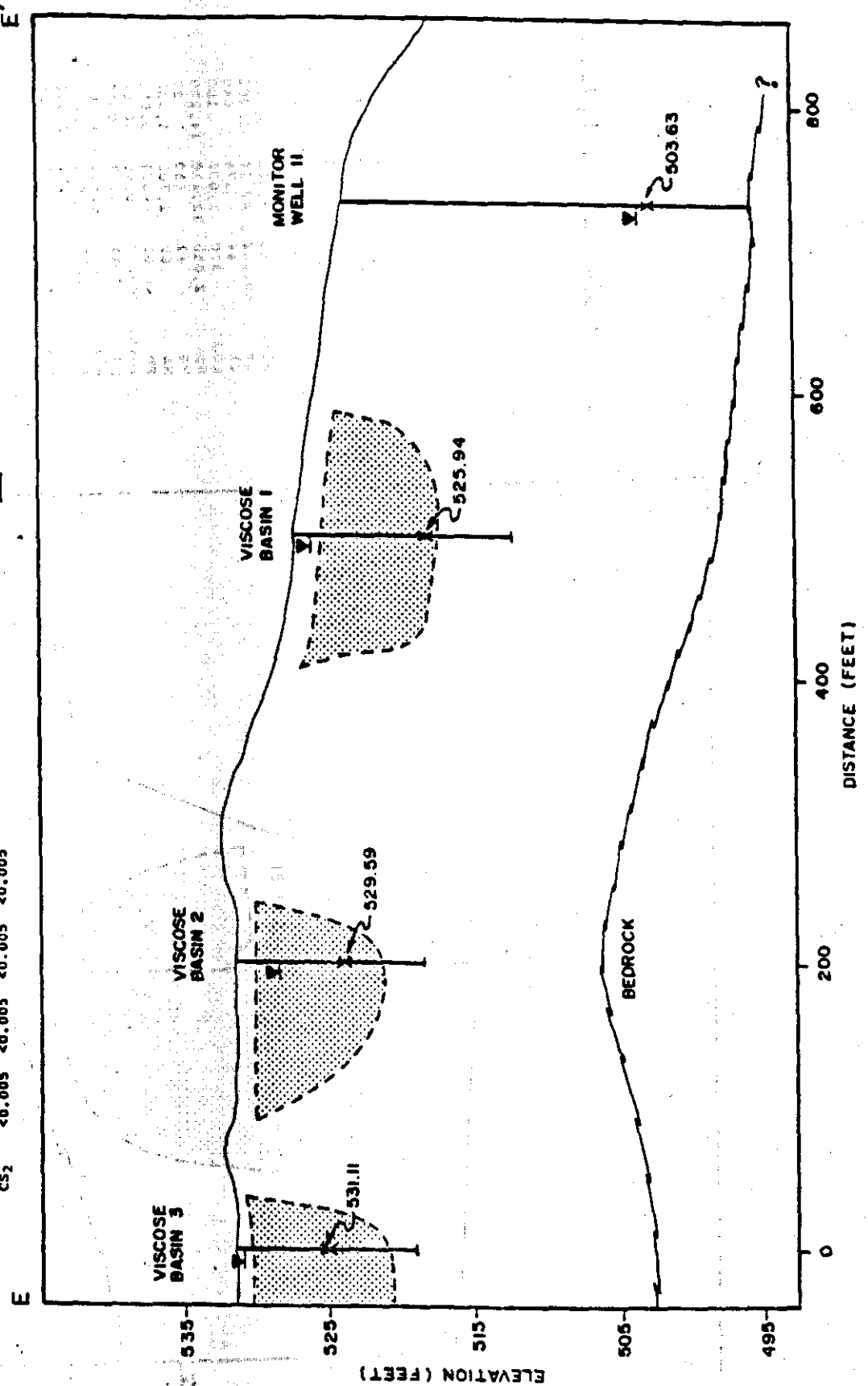
Section No.: 3.0
Revision No.: 1
Date: August 26, 1988
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WATER LEVELS: JAN. 11, 1988

GROUND-WATER SAMPLING
ROUND 2
(mg/l)

	VB-3	VB-2	VB-1	MY-11
Alk.	12,000	4,100	9,800	610
As	0.2	0.04	0.16	<0.002
Cl	520	280	380	390
COD	1,500	690	1,200	40
Sp.	15,440	6,930	32,100	5,580
Mg	86	84	150	134
Na	5,600	2,400	10,000	670
Pb	<0.2	<0.20	<0.20	<0.03
Phen.	7.1	0.02	0.2	<0.02
pH	7.63	7.49	7.48	6.05
SO ₄	170	750	9,400	2,000
TDS	14,700	5,190	29,100	4,600
Zn	0.06	0.27	0.1	0.33
CS ₂	<0.005	<0.005	<0.005	<0.005

VISCOSE WASTE



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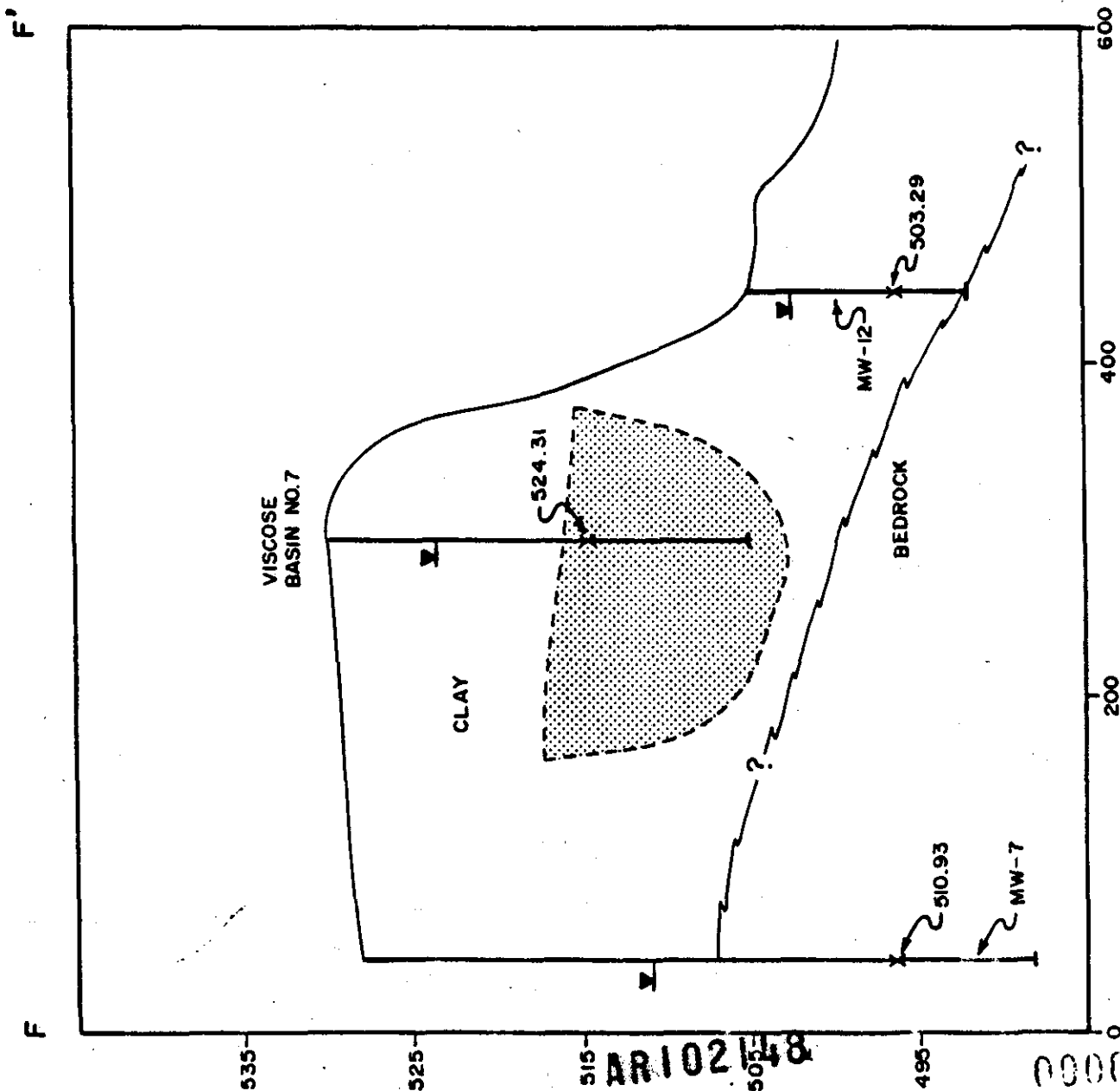
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WATER LEVELS: JAN II, 1988

GROUND-WATER SAMPLING
 ROUND 2
 (mg/l)

	MW-3	VB-7	MW-12
Alk.	160	3,500	5,000
As	<0.002	<0.04	<0.002
Cl	44	170	640
COD	320	1,000	100
Sp.	2,050	12,210	14,200
Hg	42	450	20
Na	89	2,700	3,900
Pb	<0.03	<0.2	0.058
Phen.	<0.02	0.56	<0.02
PH	7.53	6.77	9.15
SO ₄	600	4,900	4,300
TDS	1,520	13,800	12,700
Zn	2.6	0.11	0.032
CS ₂	<0.005	1.5	0.021

WASTE MATERIAL



MW series wells located hydraulically downgradient of the basins, reflect the true position of the water table. The basins probably do leak fluids to the underlying unconsolidated materials; however, in a strict definition, an unsaturated zone exists between the basin bottom and the water table. This condition is also supported by the shallow electromagnetic work performed which demonstrated that there is little lateral migration of highly mineralized fluids beyond the boundaries of Viscose Basins 1, 2, and 3. In comparing the hydraulic conditions underlying Viscose Basins 1, 2, and 3 with Viscose Basin 7/8, the unsaturated zone below Basin 7 is very limited. As will be shown in Section 4.0, this relationship is further demonstrated by the geochemical nature of the ground-water downgradient of the basins.

3.1.3 Hydraulic Head Relationship - Open Viscose Basins

Similar to activities performed at the closed viscose basins, G&M installed piezometers in Viscose Basins 9 and 11, and a well along the downgradient perimeter berm of Basins 9 and 10. Depth-to-fluid measurements were made at each installation and plotted in cross section with basin construction information in terms of elevation (Figure 3.7). In addition, depth-to-water measurements were collected from bedrock Wells MW-3 and GM-8. As indicated by the figure, fluid levels within Viscose Basins 9 and 11 are approximately at elevation 515 feet. For wells penetrating the unconsolidated material above the bedrock, the water levels are located above the base of Viscose Basins 9 (490 feet) and 11 (503 feet). Water levels collected from the bedrock Well MW-3 is at elevation 504 feet, which is near the base of basin Number 11 and considerably above the bottom of the waste material in basin Number 9. Based on personal communication with employees at Avtex, bedrock material was

WATERLEVELS: JAN 12, 1988

VISCOSE WASTE

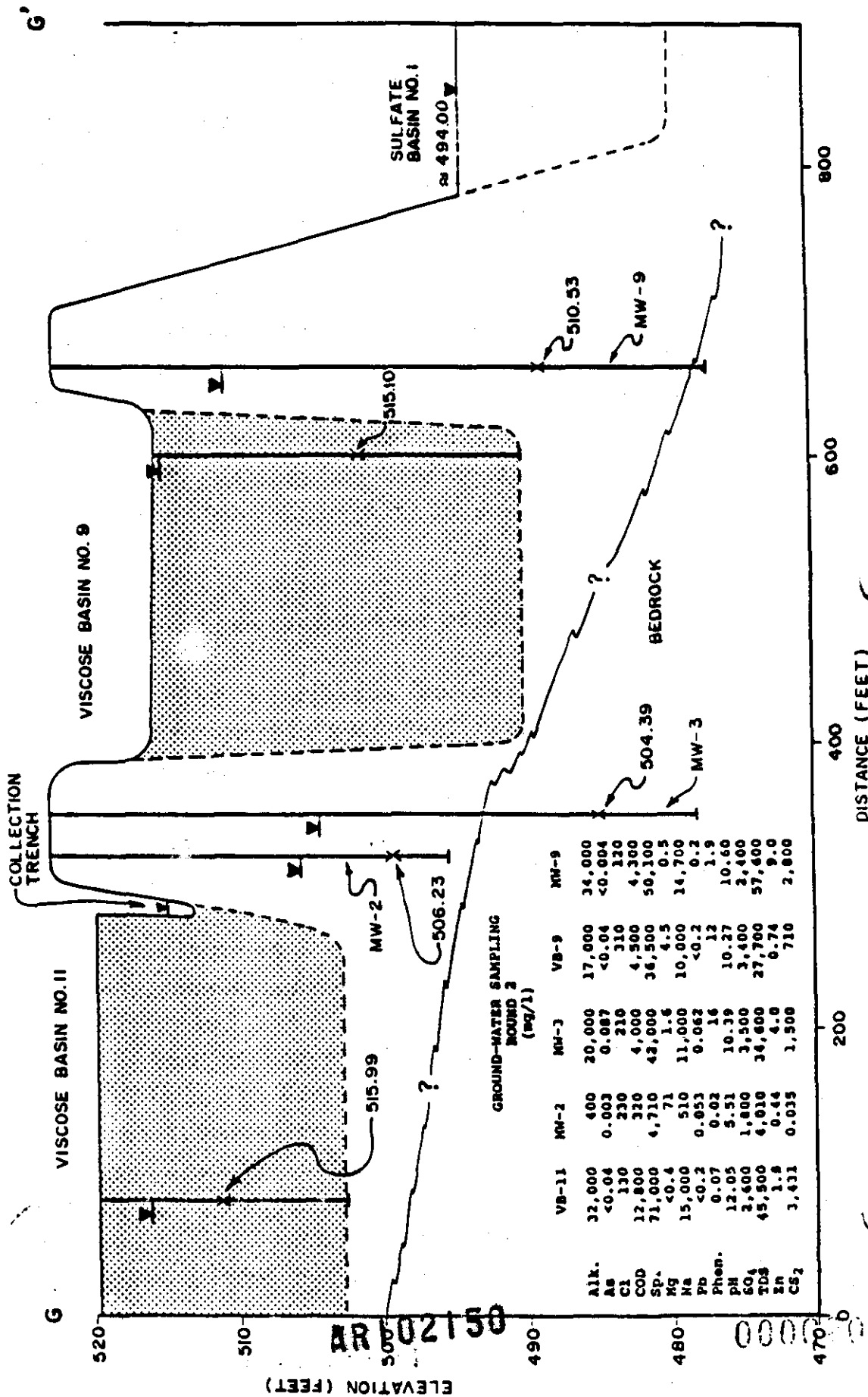


Figure 3.7 Cross-sectional depiction of Viscose Basins 9 and 11

removed during the construction of Viscose Basin 9 to increase the potential disposal volume of the basin. Although a vertically downward component of flow is determined from the measured head values from within the basins, to the unconsolidated materials, and to the bedrock, it is unclear whether the bedrock water level exhibited by Wells GM-8 and MW-3 are indicative of the true water table, or a mounding effect due to leakage of fluids through the bottom of each basin. Based on the close proximity of the bottom of basin 9 to the bedrock surface, G&M has concluded that at least this basin lies within the water table. As to the other basins, it is unclear as to whether the underlying clayey soils are unsaturated or whether direct hydraulic connection exists between the basins and the ground-water regime. It is important to point out that the fluid levels in the basin are high compared with the surrounding wells suggesting that the bottom has a permeability which reduces the amount of fluid leakage and results in increasing fluid accumulation within the basins during periods of heavy precipitation.

The comparison of the basin fluid and ground-water chemistry is presented in Section 4.0 and helps in understanding the relationship between the source areas and the underlying ground-water regime.

3.2 Facility-Wide Ground-Water Conditions

During the course of the RI field work, several complete rounds of water-level measurements were collected from the entire monitor-well network on both sides of the river. In addition, the level of the Shenandoah River was measured using a station at the Avtex river pump house. A summary of all observations is presented as Appendix H. In considering the horizontal component of flow across the facility, one

must keep in mind that the well network is represented by installations of various depths within the bedrock aquifer. Partial penetration effects will be observed in plotting the potentiometric contours, and hence some averaging of values is required. Depth-to-water measurements at the back side of the plant, Well MW-1, is at approximately elevation 544 feet (Figure 3.8). On the terrace rise in the vicinity of the viscose basins, ground-water elevation is approximately 475 feet. Along the river bank near the sulfate basins, elevation is approximately 471 feet. At Rivermont Acres along the ridge line, the estimated potentiometric head value based on well 193-91 is 540 feet. Along the Rivermont Acres floodplain, elevation is approximately 472 feet. For these measurement periods, river elevation is approximately 470 feet. As such, the horizontal component of flow (areas of higher to lower hydraulic head) is directed toward the river, representing the discharge boundary for the facility-wide section of the bedrock aquifer. Ground-water at Rivermont Acres also discharges to the Shenandoah River.

The vertical component of flow for the bedrock aquifer in the vicinity of the project area has been evaluated using the various wells installed to variable depths within the bedrock unit. The installation of well clusters has helped evaluate the direction of flow within the bedrock aquifer to the maximum depth of investigation at an approximate elevation of 315 feet. As has been demonstrated in and around the viscose basins, measured hydraulic heads within the basins, unconsolidated deposits and bedrock, indicate a downward component of flow from the open basins to the ground-water regime. By plotting the elevation of ground water as the midpoint of the open borehole section for selected wells located parallel to the horizontal component of flow, the vertical component of flow in the vicinity of the Shenandoah river is upward from the deeper portion of the

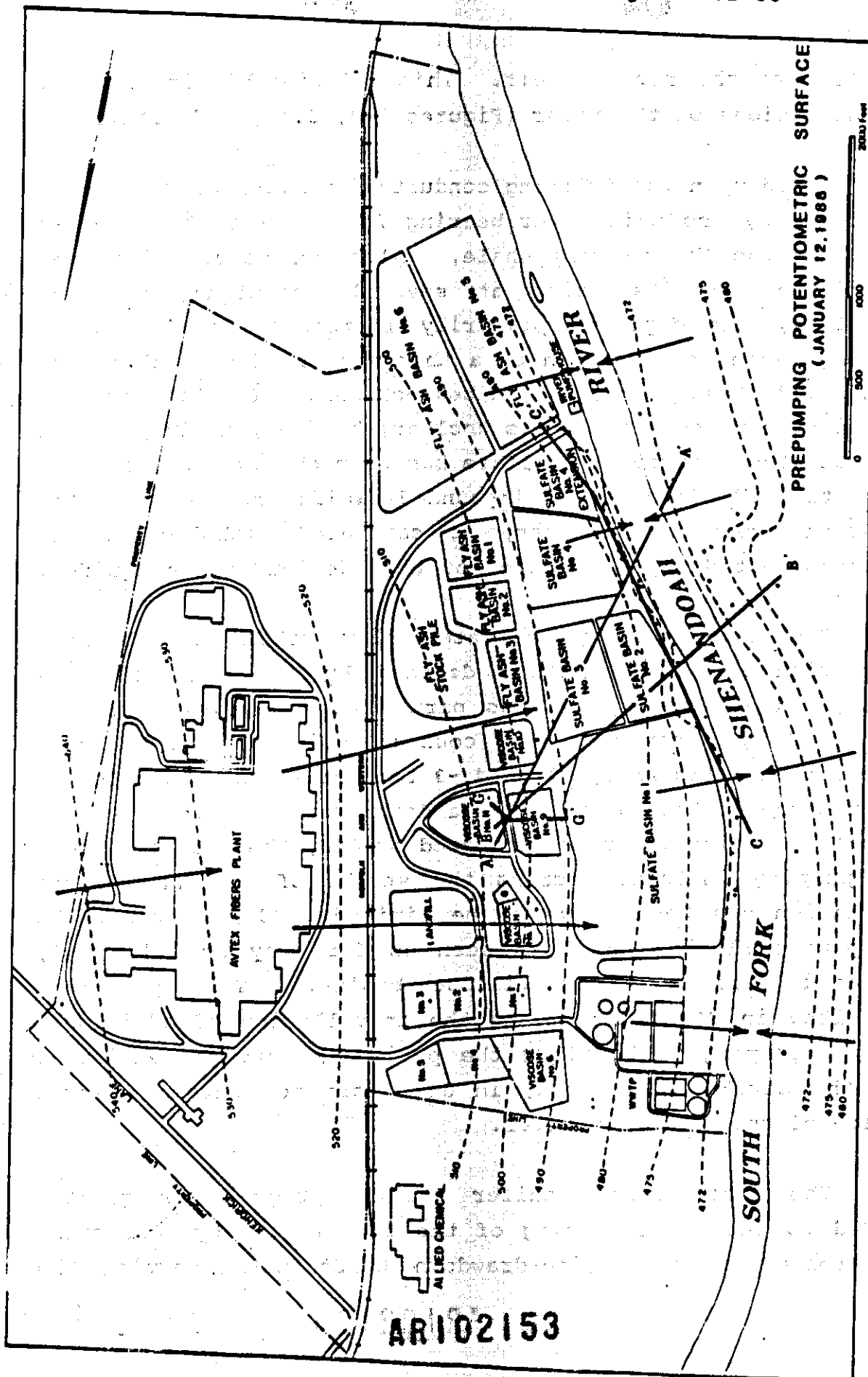


Figure 3.8 Potentiometric Surface for Bedrock Aquifer

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aquifer to the river itself. This relationship is observed on both sides of the river (Figures 3.9, 3.10, and 3.11).

Based upon the drilling conducted at Avtex over the past four years, the main water-bearing formation in the project area is the Martinsburg shale. Although saturated unconsolidated deposits exist at several locations over the facility, the deposits primarily represent reworked soils during basin construction or a thin veneer of natural silts, sands and clays overlying the bedrock unit. The lateral continuity of these deposits is unclear; however, their presence beneath the viscose and sulfate basins probably decreases the unrestricted migration of impounded fluids from reaching the bedrock aquifer. However, as saturated lithologies, the unconsolidated deposits have not been defined as an aquifer.

The nature of ground-water flow within the bedrock formation has been further defined by the aquifer tests conducted in January 1988 as part of the RI field program. Since 1984, Avtex has been counterpumping degraded ground water from wells PW-1, -2, and -3 to contain the migration of contaminants toward the Shenandoah River. In previous aquifer testing programs conducted by G&M, the lateral extent of pumping influence across the strike of the Martinsburg Formation has been shown to be limited. Along strike, the pumping influence has been seen as far away as Well GM-8, located near the open viscose basins. This phenomena resulted in G&M recommending the installation of additional counterpumping wells along the perimeter berm perpendicular to the strike of bedrock, in an effort to contain a large slice of the bedrock aquifer.

The most recent aquifer testing program has greatly added to the understanding of the flow regime by conducting controlled constant rate-drawdown tests and observing the

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PRE - PUMPING CONDITIONS (JAN 12, 1988)

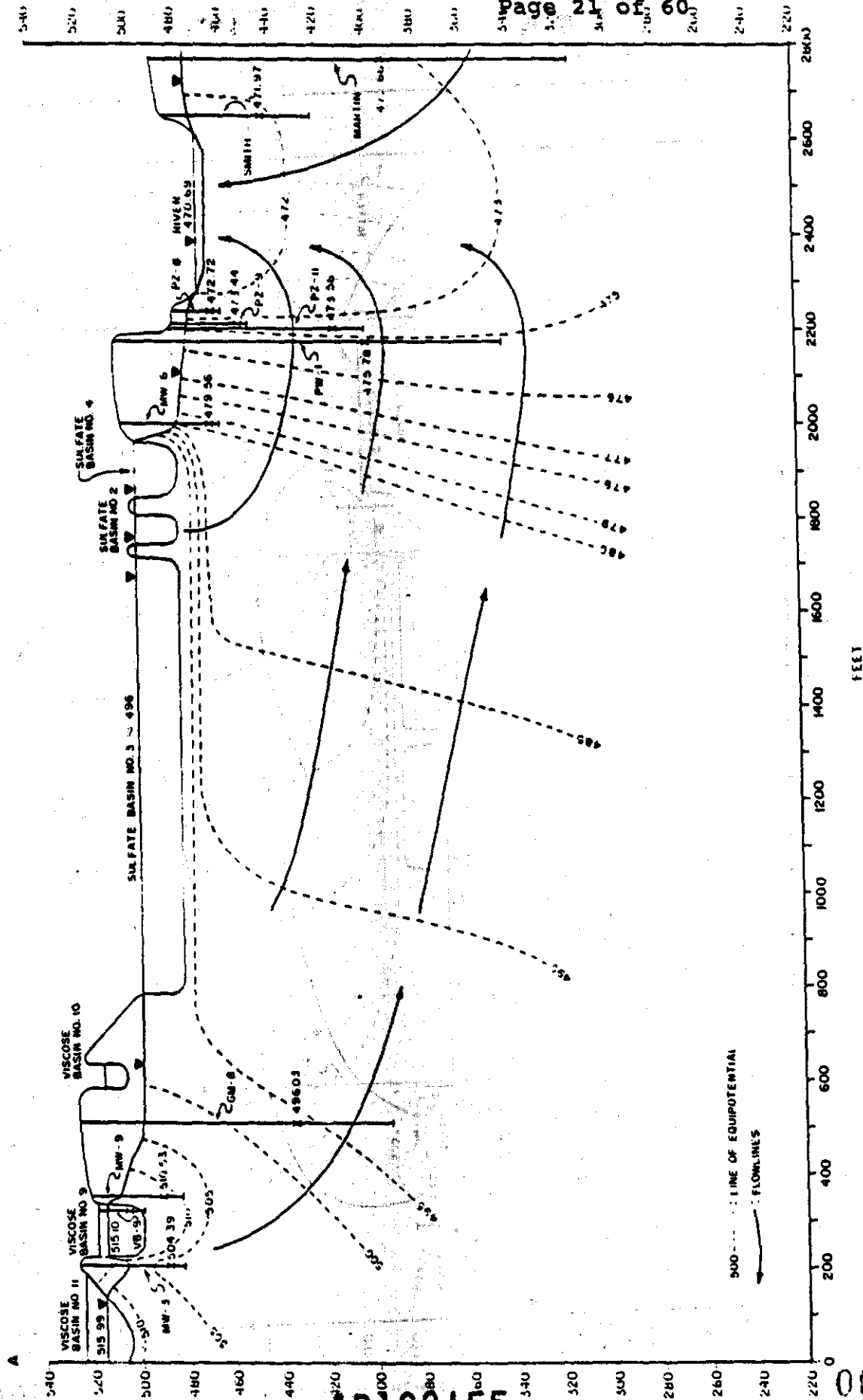


Figure 3.9 Ground-Water flow Conditions (non-pumping) Section A-A'

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PREPUMPING WATER LEVEL ELEVATIONS

(All measurements made on 1-11-88 exca. Ritter, Ritter was measured on 1-12-88)

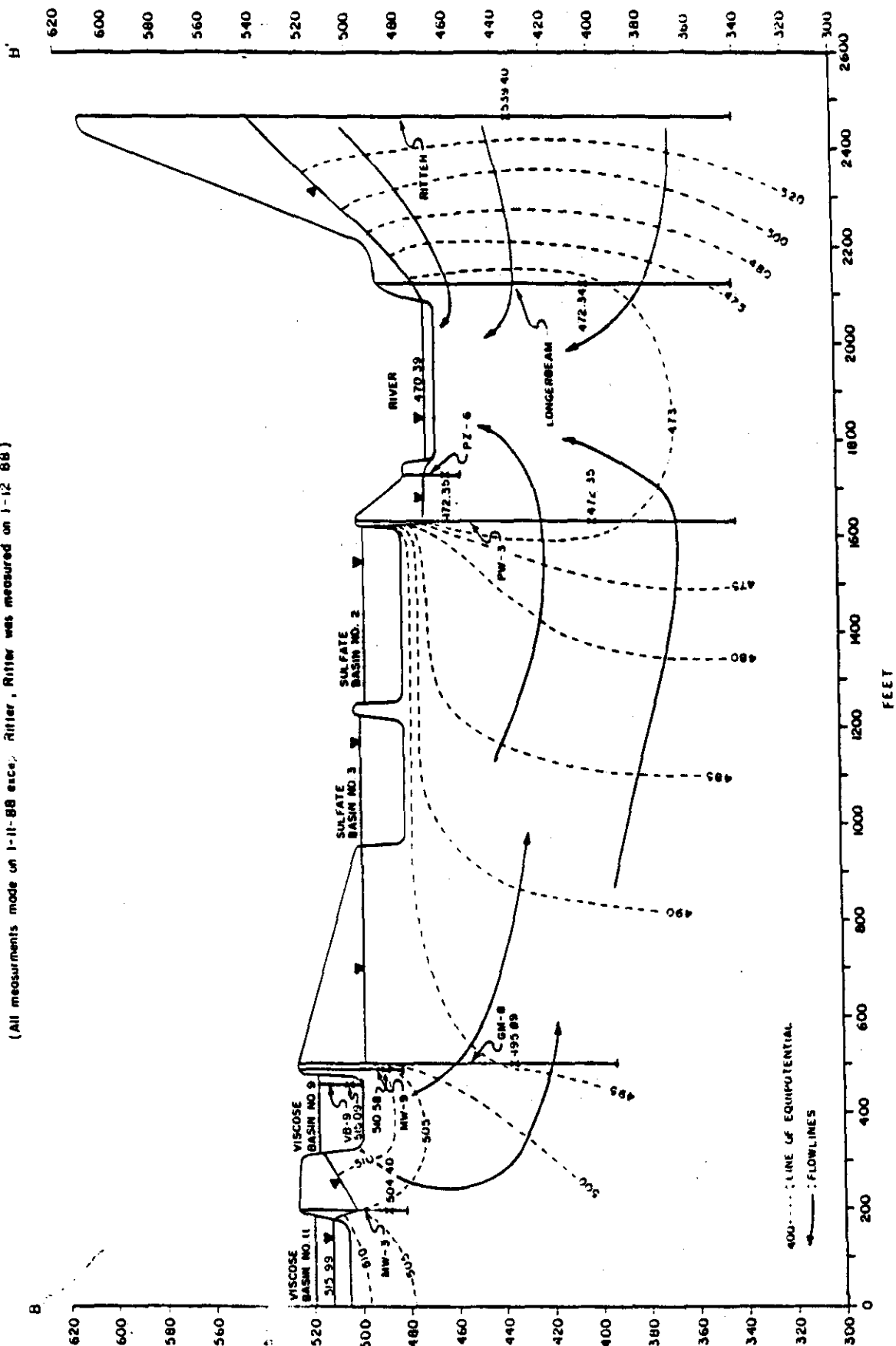


Figure 3.10 Ground-Water Flow Conditions (no pumping) Section B-B'

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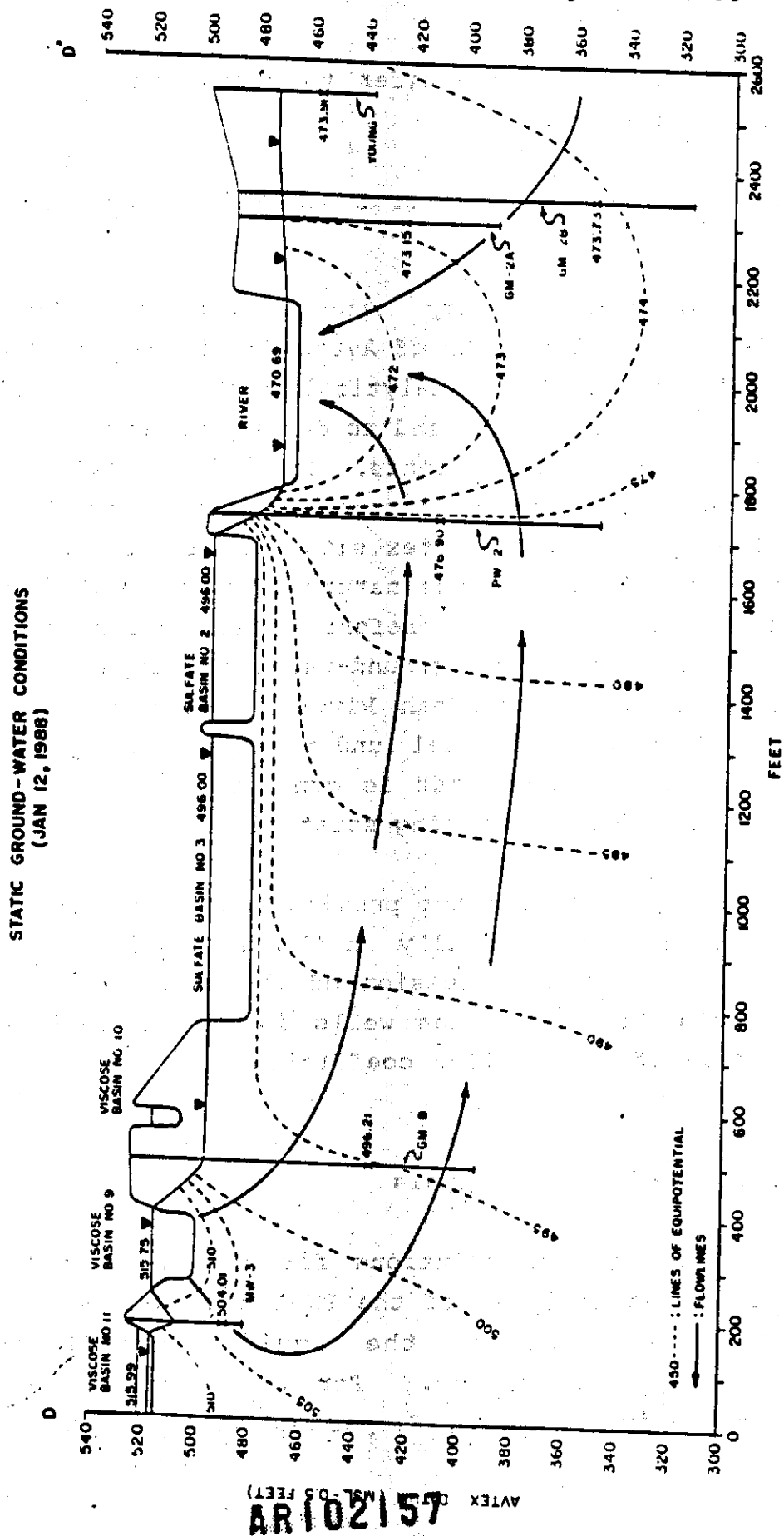


Figure 3.11 Ground-Water Flow Conditions (non-pumping) Section D-D'

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response of the bedrock aquifer to stress on both sides of the Shenandoah River.

3.3 RI Conducted Aquifer Tests and Ground-water System Evaluation

Drawdown and recovery measurements made during the constant-rate pumping tests of Avtex Wells PW-1 and PW-3 were analyzed by appropriate analytical methods to examine the areal influence of pumping and to determine aquifer transmissivity and storage coefficients. In these analyses, special attention was given to two important features of the ground-water flow system at the Avtex site that influence rates and directions of flow: (1) the nature of flow in the fractured bedrock aquifer including preferred flow orientations, and (2) potential sources of ground-water recharge such as the South Fork of the Shenandoah River. The results of these analyses yield a conceptual understanding of ground-water flow at the Avtex site that is consistent and suitable for designing ground-water pumping strategies.

The analyses of the two pumping tests at Wells PW-1 and PW-3 are treated individually in the discussion below. For each test, a general discussion of the pumping influence on water levels in observation wells is given, followed by a presentation of the aquifer coefficients determined from the test.

3.3.1 Method of Analysis

Analytical solutions for ground-water flow were employed in the analyses of the PW-1 and PW-3 pumping tests in order to determine the aquifer coefficients of transmissivity and storage. For the drawdown tests, the methods of Theis (1935) and Cooper and Jacob (1946) were used

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to analyze the data. For the recovery portions of the tests, the data were analyzed by the Theis (1935) recovery method. While these solutions are intended for the analysis of flow in granular porous media with no outside ground-water sources or sinks, their use can be extended to determine aquifer coefficients in certain fractured rock aquifer systems and systems influenced by rivers or impermeable boundaries.

The Theis equation for determining drawdown under nonequilibrium conditions is given as (Kruseman and De Ridder, 1979):

$$s = \frac{Q}{(4 \pi T)} \int_u^{\infty} \frac{e^{-u}}{u} du = \frac{Q}{(4 \pi T)} w(u)$$

where

- s = drawdown, [L]
- Q = well discharge, [L³]
- T = coefficient of transmissivity, [L²/T]
- w(u) = Theis well function
- u = r² S / (4 T t)
- r = radial distance from pumping well to observation well, [L]
- S = coefficient of storage, dimensionless
- t = time, [T]

The coefficients of transmissivity and storage are usually determined by matching the observed drawdown data plotted as a function of time to a "type curve" of the Theis well function plotted as a function of the variable u. The data and type curve are plotted on separate sheets of double logarithmic graph paper, and the two plots are adjusted until a suitable match between the data and the type curve is obtained. With this match, it is possible to compute T and S from the position of the "type curve."

The Cooper-Jacob (1946) drawdown analysis method is a simplification of the Theis drawdown method. In this method, the Theis well function is approximated as a straight line for values of the variable u less than about 0.01. The data are plotted as a function of time on semi-logarithmic graph paper, and a straight line is drawn through the data. The values of T and S are computed from the slope of the line and the intercept of the line on the time axis.

The Theis (1935) recovery method is also a "straight line" technique. Residual drawdown (the drawdown remaining after pumping has stopped) is plotted as a function of the ratio of time since pumping began, to time since pumping stopped on semi-logarithmic graph paper. An assumption of the method is that the coefficient of storage during pumping and recovery is constant. As a consequence, only transmissivity can be determined by this technique.

More detailed information concerning the theory, assumptions, and use of the three aquifer test analysis methods mentioned above can be found in Kruseman and De Ridder (1979) and Driscoll (1986).

In the analyses of the two aquifer tests conducted at Avtex Fibers in January 1988, special attention was given to the fractured nature of the bedrock aquifer and the potential for river recharge to the aquifer during the tests. The effect of both of these conditions is to cause the response of the aquifer to depart from strict Theis behavior as the aquifer test progresses.

The effect of river recharge to an aquifer is easily detected by the Theis drawdown, Cooper-Jacob, and Theis recovery methods used in this analysis, and determination of aquifer coefficients is not complicated.

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Figure 3.12 shows the effect caused by a recharge boundary in the Cooper-Jacob method. Transmissivity and storage coefficients are determined from the early portion of the graph prior to about 240 min before recharge effects are present. It is also possible to estimate aquifer transmissivity with these methods in the case of fracture flow. This behavior will be observed when the fractured aquifer behaves as an equivalent porous medium, or, in the case of a dual-porosity model (Moensch, 1984), at early and late times during the pumping test.

To analyze the effect of recharge barriers such as a river, the Theis and Cooper-Jacob drawdown methods can be used in conjunction with the principle of superposition. In the case of a fully penetrating river, an "image well" is placed on the opposite side of the river from the pumping well, at a distance equal to that between the pumping well and the river, and injects water into the aquifer at a rate equal to the pumping rate of the test well. The net effect of these two wells results in zero drawdown at the river. For observation wells, the drawdown due to the pumping well and the impressed head resulting from the image well are added together in order to compute actual drawdowns.

In the case of a river that is not fully penetrating (i.e., it is not a barrier to flow), drawdown actually occurs beneath the river. The effect of the river can be simulated by adjusting the radial distance between the observation well and the image well (Hantush, 1959). The objective of this adjustment is to move the position of zero drawdown in the aquifer a greater distance from the pumping well. For a complete discussion of image wells, the reader is referred to Kruseman and De Ridder (1979).

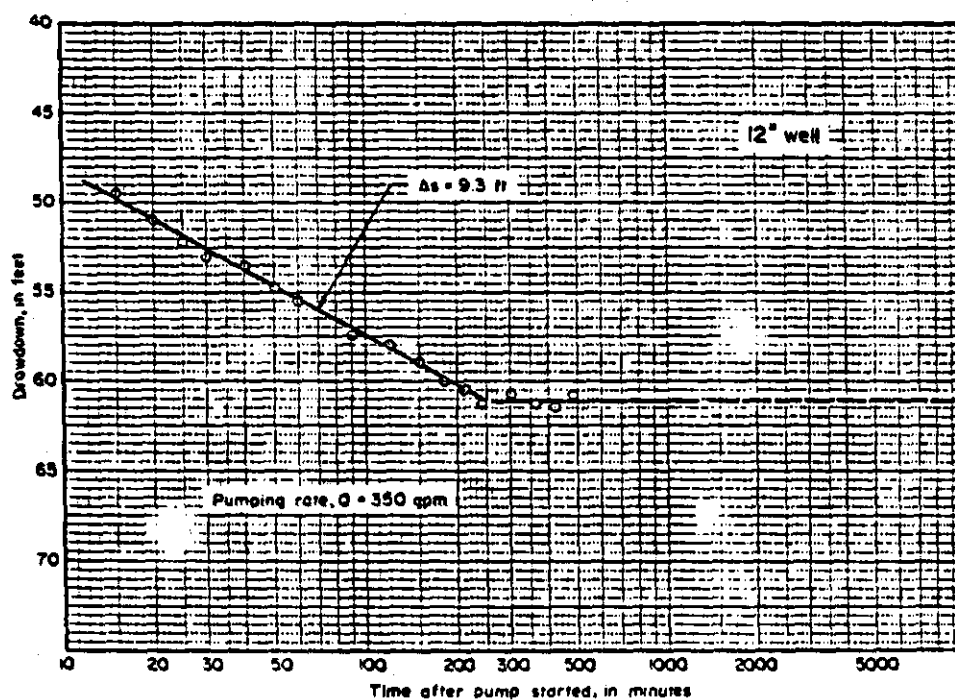


Figure 3.12 Example of the Effect of a Recharge Barrier on Drawdowns in a well. Drawdowns reach a steady value after boundary is reached (from Driscoll, 1986, p.225)

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The three aforementioned methods of determining aquifer coefficients are performed typically by graphical interpretation techniques. Computer programs using nonlinear least-squares regression techniques are also available to analyze aquifer test data by these three methods. In this investigation, a hybrid technique, using both graphical and nonlinear least-squares methods, was used to analyze the drawdown and recovery data from the aquifer tests. The computer program AQTESOLV, developed by G&M (Modeling Group), was used to perform this combined analysis.

3.3.2 PW-1 Pumping Test

A constant rate pumping test in Well PW-1 began on January 13, 1988. A pumping stress rate of $5.41 \text{ ft}^2/\text{min}$ (40.5 gpm) was initiated 1715 hrs and continued for 1490 min until 1805 hrs on January 14. During the test, drawdown measurements were made in the pumping well, and in 18 observation wells in the vicinity of PW-1. After pumping stopped, recovery in these wells was measured for 180 min.

Observation wells monitored during the PW-1 test were located on both the east and west sides of the South Fork of the Shenandoah River. Table 3.1 identifies these wells and their radial distances from the pumping well. A total of eleven observation wells were located on the east side of the river (the same side as PW-1); seven observation wells were situated on the west side. GM-9 was closest to the pumping well at a radial distance of 35 ft. The well farthest from PW-1 was MW-3 at 1750 ft. Water levels in nine observation wells were measured by continuous recorders, while nine others were monitored by hand measurements.

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TABLE 3.1
WELLS MONITORED DURING PW-1 PUMPING TEST,
JANUARY 13-14, 1988, FRONT ROYAL, VA

Wells monitored on east side of river

<u>Well No.</u>	<u>Radius from pumping well (ft)</u>
PW-0	240
PW-1	(pumping well)
PW-2	315
PZ-6	510
PZ-7	310
PZ-8	150
PZ-9	170
PZ-11	130
GM-8	1435
GM-9	35
MW-3	1750
MW-6	190

Wells monitored on west side of river

<u>Well No.</u>	<u>Radius from pumping well (ft)</u>
GM-2A	590
GM-2B	635
FRUM	935
MARTIN	650
SCHILLING	565
SMITH	550
YOUNG	785

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